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OPERATIONAL SUPPORT FOR PLANT BREEDING AND RELATED RESEARCH AT THE CROP DEVELOPMENT CENTRE

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Executive Summary

The Crop Development Centre continues to provide genetic improvement to Saskatchewan and western Canadian farmers and the agricultural industry in all crop kinds in its mandate. Cultivar recommendation in 2008 (29 cultivars) and 2009 (23 cultivars) have been very encouraging. The Crop Development Centre exemplifies a successful partnership model between public and private sector, with core funding from Saskatchewan Ministry of Agriculture, indirect funding and infrastructure supplied by the University of Saskatchewan, and operational funding provided through a myriad of research agreements with public and private sector as well as royalties from variety licensees. A healthy agricultural industry is based on sun, water, soil and seed. The CDC maintains its focus on research, development, breeding, and quality management of initial breeder seed, in order to provide good varieties – the seed – of the equation.

Plant Breeding Accomplishments and Progress

The Crop Development Centre plant breeders received recommendation for all cultivars put forward for recommendation in February 2009, for a total of 22 new cultivars for market consideration. They are as follows:

Cultivar	Crop Kind	Licensee
IBC-194	Large green lentil (Clearfield Resistant (CL))	Sask Pulse Growers (SPG)
IBC-187	Medium red lentil (CL)	SPG
1897T-30a	Extra small red lentil	SPG
2271-5	Small red lentil (CL)	SPG
2275-15	Large red lentil	SPG & SaskCan Pulse Trading
2321-6	Small red lentil (CL)	SPG
3056-12	Green cotyledon	SPG & SaskCan Pulse Trading
2005S-1	Pinto bean	SPG & Walker Seeds
2793 CBB	Pinto bean	SPG & Walker Seeds
CDC 1897-14	Yellow pea	SPG
CDC1897-3	Yellow pea	SPG
CDC 1932-201	Green pea	SPG
BW 880	CWRS Wheat	Viterra
BW 881	CWRS Wheat	To be determined (TBD)
BW 883	CWRS Wheat (midge resistant)	TBD
PT 575	CWRS Wheat (CL)	TBD
09SPELT4	Spring Spelt	TBD
GP 003	General Purpose Wheat	TBD
HB 402	Hulless Barley	TBD
SR 420	Six-row Malt Barley	TBD
OT3036	Milling Oat	Cargill & Quaker
FP 2242	Flax	SeCan

In 2008 the CDC received recommendation for 29 new cultivars listed below. As a follow-up, the current status of varieties moving forward to commercialization is indicated as follows.

Cultivar and Crop Kind		Variety Name (Licensee)
CDC 2154S-4	small red lentil	Not named yet (Sask Pulse Growers)
CDC 1788S-4e	extra small red lentil	Not named yet (SPG)
CDC 1899T-50	extra small red lentil	Not named yet (SPG)
CDC 1894T-1	extra small red lentil	Not named yet (SPG)
IBC-145	medium green lentil (CL)	Not named yet (SPG)
IBC-112	small green lentil (CL)	Not named yet (SPG)
IBC-188	French green lentil (CL)	Not named yet (SPG)
CDC 1681a-6	black bean	Not named yet (SPG)
CDC 1571a-13	great northern bean	Not named yet (SPG)
CDC 1702-17	pinto bean	Not named yet (SPG)
CDC 1749-8	yellow pea	Not named yet (SPG)
CDC 1812-5	green pea	Not named yet (SPG)
ICC 12512-1	desi chickpea	CDC Corinne
DT 540	durum	CDC Verona (Paterson Grain)
TR 105102	two row malt barley	CDC Landis (P&H)
TR 105104	two row malt barley	CDC Meredith (SeCan)
TR 05912	two row malt barley	CDC Reserve (SeCan)
TR 06918	two row malt barley	CDC PolarStar (Canterra)
TR 05915 (collab)	two row malt barley	Norman (FP Genetics)
TR 06389	two row feed barley	CDC Austenson (SeCan)
HB 390	hulless barley	CDC Carter (SeCan)
SR 410	six row malt barley	CDC Kamsack (Canterra)
SR 412	six row malt barley	CDC Mayfair (Canterra)

Plant Breeding and Research Highlights

In addition to plant breeding, CDC scientists are involved in a large number of research projects that contribute to genetic improvement. These are described in detail in this report. A few examples include:

- Continued and expanded development and use of molecular tools in all breeding programs
- First CDC wheat midge resistant CWRS cultivar BW883
- Research into high amylose trait in wheat and durum and its effect on glycemic index
- Significant increase in resistance to leaf spotting complex in new wheat cultivar BW880
- Release of spring wheat cultivar BW881 with improved competitive ability to weed pressure
- Marker development for high grain protein in durum
- Marker development for fusarium resistance in durum and spring wheat
- UG99 screening in wheat in collaboration with AAFC Winnipeg
- Marker development for crown rust resistance in oat
- Wheat varieties for ethanol production
- First hulless malt barley cultivar HB402 released

- First high amylose hulless food barley cultivars in test
- EST and SNP development in flax and pulses
- High oleic oilseed flax in development
- Successful development of Canada's first slow-darkening pinto bean varieties
- Optimizing fungicide use for ascochyta control in chickpea
- Genetic characterization of physical quality traits in pea for increased marketability to food markets
- Doubled haploidy advancement in pea and chickpea

Scientific Publication and Technology Transfer

- 75 extension presentations and field days
- 77 conference presentations / posters, including four as invited speakers
- 41 refereed manuscripts
- 7 international activities

Graduate Student Supervision

- 19 graduate students supervised

Summary

The CDC enjoyed a successful and productive year in 2008-09 and looks forward to further success in 2009-10. The strategic financial support provided by Saskatchewan Ministry of Agriculture to the CDC is fundamental to the CDC's output. The CDC is a well known brand throughout Canada's agricultural value chain, from seed growers and farmers, to agricultural distribution and grain handling companies, to end users, and its breeders and scientists are known world wide for their productivity, competence and sound science.

The CDC looks forward to continued support from the Saskatchewan Ministry of Agriculture as we work together to enhance Saskatchewan's agriculture industry.

Respectfully submitted,

Dorothy Murrell
Managing Director

CDC Administration

The CDC Managing Director and office staff provide strategic direction, contract development, commercialization, financial reporting and operational support to the CDC scientists and technical staff. In 2008-09 the CDC office developed 13 field crop variety licenses, numerous horticulture crop variety licenses, 13 research agreements with private sector and grower organizations, and six material transfer agreements.

Commercialization Activities

Royalties earned on CDC varieties totalled approximately $862,000 in 2008-09. Thirty-five percent of these funds are used to support the central operating costs of the Centre and the remaining 65% is allocated back to the breeding program that generated the revenue.

During 2008-09, the following variety license agreements were finalized:

License Agreements	Licensee
CDC PolarStar	Sapporo; Canterra
CDC Reserve	Sapporo; SeCan
CDC Mayfair	Canterra
CDC Kamsack	Canterra
CDC Meredith	SeCan
CDC Landis	P&H
CDC Clyde	Viterra
Peregrine	SeCan
Accipiter	SeCan
Haskap / sour cherry	multiple
Columnar apples	DNA Gardens
CDC Linalool	Emerald Seeds
CDC Verona	Paterson Grain

Research Funding

The Crop Development Centre depends heavily on financial support received from a wide variety of sources:

- SMA provides an annual operating grant of $1,000,000 to the CDC. In addition, in 2008-09, approximately $1,200,000 in funding from other sources was used to support the operation of the Centre.
- CDC is successful in negotiating strong research and breeding support from private sector, grower, and public sector organizations.
- Total research funding held by CDC scientists in 2008-09 totals approximately $8 million.

New research agreements in 2008-09 with private sector and grower organizations include:

Research Agreement	**No. of Years**
SeCan barley agreement	10
Sapporo barley agreement	3
Secan GP wheat agreement	10
Quaker Oat renewal	3
SODC oat agreement	5
SCDC canaryseed agreement	5
PBI flax & pulse agreement	1
WGRF Endowment Durum	3
WGRF Endowment Wheat	3
WGRF Endowment Oat	3
Paterson Durum agreement	3
Total Commitment	$ 1,205,000

New research agreements in 2008-09 with public sector funding organizations include:

Title	**Funding Agency**	**No. Years**
Spot blotch and net blotch resistance in barley	ADF	3
High pigment wheat for anti-oxidant potential	ADF	3
Optimizing fungide application in chickpea	ADF	4
Mining pulse seed coat for dietary and economic benefits	ADF	3
Genetic improvement of selenium content in lentil seed	ADF	3
Mining of CDC Bethune for DNA markers	ADF	3
High oleic flax with enhanced oil concentration	ADF	3
Canaryseed disease resistance and DNA marker development	ADF	5
Allele diversity for nutritional profile and disease resistance in pea	ADF	3
Designer cereal grains for the biofuel industry	ADF	5
Off season (winter) nursery for flax	ADF	5
Total ADF 2008-09 awards	$ 2,290,800	
Low phytate phosphorus pea	NSERC	5
National deployment gene strategy	NSERC/U OF G	3
Functional genomics in durum wheat	NSERC/U of A	3
Total NSERC 2008-09 awards	$ 760,980	

In addition, CDC scientists are involved in Genome Canada and ABIP projects.

Market Share and Royalties

CDC varieties hold good to strong market share in western Canada as estimated from a number of industry statistics:

- 78% of flax acres (CDC Bethune, CDC Sorrel)
- 75% of winter wheat acres (CDC Falcon, CDC Buteo, CDC Raptor, CDC Clair)
- 38% of CWES acres (CDC Rama)
- 10% of CWRS acres (CDC Teal, CDC Imagine, CDC Go, CDC Alsask)
- 34% of two-row malt barley acres (CDC Copeland, CDC Kendall)
- 89% of two-row hulless barley acres (CDC McGwire, CDC Fibar)
- 32% of two-row feed barley acres (CDC Dolly, CDC Bold)
- 35% of oat acres (CDC Dancer, CDC Boyer, CDC Orrin, CDC Weaver)
- 50% of pea acres (CDC Golden, CDC Striker)
- 90% of lentil acres (CDC Rouleau, CDC Blaze, CDC Redberry, CDC Impact)
- 96% of chickpea acres (CDC Frontier, Amit)

In addition, a number of CDC varieties are grown in eastern Canada (eg. CDC Orrin) and in the northern Great Plains of the US (eg. CDC Golden, CDC Striker, CDC Falcon).

Royalties to the CDC from variety license agreements totalled approximately $1.08M in 2008-09.

Grains Innovation Laboratory Capital Project

The CDC MD managed the transition of the Grains Innovation Laboratory from the design phase to its present build phase. The Grains Innovation Laboratory project is located at the Agriculture Research Park at Preston Avenue and 108th Street. Expected completion date is in fall 2009. Base funding was provided by Saskatchewan Ministry of Agriculture and Agriculture and Agri-Food Canada. The CDC has contributed funding as well. A fundraising campaign was mounted by the CDC for this project in spring 2008, which has yielded corporate sponsorship to date of $500,000.

Personnel

The CDC has identified the increasing administrative requirement from funding agencies as a concern and a consideration for increasing support services.

CDC Quality Laboratory

The CDC Quality Laboratory will soon be housed in the new Grains Innovation Laboratory. Operation of the Quality Laboratory is funded through the operating grant provided to the CDC by the Saskatchewan Ministry of Agriculture. CDC Quality Lab professionals coordinates with the professionals at the Canadian Grain Commission's Grains Research Laboratory and the Canadian International Grains Institute, in order to ensure that protocols for grain quality testing are the same or yield comparable results.

The primary objective of the Quality Laboratory is to assist the plant breeders of the CDC in the development of new varieties through evaluation of the quality attributes important for each crop type. To achieve this end, testing procedures must be monitored and new methods introduced when required. The technology most widely used across all the crops types is Near Infrared Reflectance spectroscopy (NIR). There are currently three NIRS6500 units in the labs, which are used to screen tens of thousands of early generation breeder lines for protein concentration; pigment content (durum wheat); oil/protein content of flax; fibre, beta-glucan and many other constituents of feed and food barley; and several components of the various pulse crops (chickpeas, dry beans, field peas and lentils). The more advanced breeder lines are screened for a wide range of quality attributes, depending on the crop. Durum and bread wheat quality testing involves as many as twenty different procedures, from protein content using the Leco analyser, various ground meal screening tests, flour and semolina milling, and finally the more complex and time consuming farinograph and baking procedures. Malting barley quality evaluation is also quite complex, with two micro-malters working continuously for several months, and the efficient Skalar unit for measuring beta-glucan, alpha-amylase, diastatic power and free amino nitrogen.

The Crop Quality laboratories are well equipped to carry out a diverse range of testing methods. However, older testing units need replacing occasionally, and new or improved methodologies often require new equipment purchases. During the past year, a new Gas Chromatograph was purchased to replace an older model for the Flax breeding program. A new Fibertec fibre extraction system was purchased to allow greater throughput in determining total dietary fibre in barley. Several UDY grinders were bought to replace older units, as were a number of computers. As a cost efficiency measure, a zero air generator and a hydrogen generator have been purchased for use in the new Grains Innovation Lab, to replace the use of gas cylinders. After the move to the GIL, a pasta production system (pasta extrusion and drying) will be introduced to enhance the durum breeding program. Cooking and/or canning quality of pulse crops is also an area that may be explored and considered for inclusion in pulse quality testing. The limitation of introducing these new tests is the number of personnel, as these advanced tests are time-consuming, requiring a certain level of expertise, and the current the workload of many of the technicians is quite demanding.

The 2008 crop year brought thousands of samples through the Quality Laboratories. The primary objective of the program is to assist the breeders in developing new varieties, and the results at the yearly variety registration meetings gives an indication of the lab's success. At the 2009 PGDC meetings in Banff, 24 new cultivars from the CDC were supported for recommendation for registration. The Quality Lab professionals and staff are proud of their role in supporting the development of these cultivars by providing reliable quality data to the breeders to assist in selection of lines with improved quality.

CDC Farm Operations

The CDC farm operations are supported through the operating grant provided to the CDC by the Saskatchewan Ministry of Agriculture.

The 2008 growing season began with cool, dry conditions during the months of May and June. This resulted in poor crop establishment, reduced herbicide efficacy and delayed crop development. However, the month of July was wetter and warmer than normal, helping to enhance crop development. Yields were near normal which was surprising given the poor growing conditions early in the season. Crop quality was reduced somewhat to August rains combined with wheat midge and sawfly damage.

The past year saw the installation of an 1176 foot linear irrigation system on land located within the city limits. This irrigation will support much of the pulse crop pathology research and will be available to irrigate early generation wheat and durum breeding material. The system utilizes low pressure drop nozzles to allow for uniform water application and minimizing water losses to evaporation.

The commercial farm operation saw the addition of a new class VII New Holland 9060 combine. This combine should greatly reduce harvest time resulting in better crop quality and much improved straw and chaff spreading capability. This will provide more uniform fertility conditions for the various research programs. Other equipment purchased includes a new zero-till planter for the breeder seed operation, four ¾-ton pickups and two goose-neck trailers. Additionally, three new research drills were fabricated in-house to alleviate the demand by the various research programs.

During the past year two new rotations were initiated on the Nasser land. One rotation was set up to facilitate agronomy research and the other was started to support the production of breeder seed.

The CDC has made significant progress in renewing its research infrastructure. Examples of this include the soon to be completed Grains Innovation Laboratory (above) along with the Pulse Lab addition to the Crop Science Field Lab. These two projects will have resulted in significant improvements to the CDC's research infrastructure. Other projects the CDC would like to initiate to continue infrastructure renewal include:

- An expanded mechanical shop at the CSFL to support the maintenance and fabrication of research equipment utilised by the various research programs within the CDC. Estimated cost is $1.5M.
- A 100' x 150' Coverall building to provide all weather storing of plant material and to facilitate the threshing of plant breeding material in the fall. During the winter this facility could also be used for the storage of the CDC's field research equipment. Estimated cost is $250,000
- Installation of a linear irrigation system on the Preston Avenue field to permit for more uniform and efficient irrigation for the CDC's various plant breeding programs. Estimated cost is $350,000.

The commercial farming operation is also grateful to Morris Industries, Bayer Crop Science and Brandt Industries for their in-kind contributions to the successful operation of the CDC Farms.

Spring Wheat Breeding and Genetics

Principal Investigator: Pierre Hucl

Objectives

- Develop spring wheat cultivars (CWRS, CWHW, hulled wheat, low amylose, etc) adapted to Saskatchewan and adjoining regions with improved yield-maturity relationships, quality and disease resistance.
- Identify shorter-strawed, medium to early maturing varieties.
- Incorporate new sources of disease resistance into the existing germplasm base. Incorporate and evaluate new and existing sources of fusarium head blight resistance.
- Assist in technology transfer regarding wheat management and variety commercialization to the Saskatchewan and Canadian wheat industry.
- Introduce and evaluate unique wheat germplasm for alternate end-use suitability and adaptation to Saskatchewan growing conditions.

Plan to Achieve Objectives

For the majority of breeding populations we will use a Modified Mass Selection procedure to handle early generation populations wherein visual selection for higher heritability agronomic traits and rust resistance is practiced. Populations in the F4 and F5 generations will be grown in an irrigated nursery in order to promote height differentiation and lodging. Higher priority populations will be "fast-tracked" by using winter nursery facilities or single seed descent in the greenhouse. In the F6 generation, experimental lines will be grown in an unreplicated yield trial format in order to eliminate agronomically undesirable material (late-maturing, tall, weak-strawed, segregating for morphological characters). Quality testing will be initiated in the F_6-F_7 generation and continued for up to three years. In the final year of CDC, multi-location yield-testing, extensive quality evaluation will be conducted. Superior lines will be advanced to pre-registration trials.

Crosses involving new sources of disease resistance (identified by the Wheat Pathology Project) will be made. Selection for disease resistance will occur in artificially-inoculated rust (irrigated) and bunt (dryland) disease nurseries for lines entered in Advanced Generation and Preliminary Bread Wheat Yield Tests (PBWYT). A minimum of 100 foreign cultivars or experimental lines will be introduced and subjected to preliminary agronomic tests. Promising introductions will then be evaluated for end-use quality and diseases resistance.

Results

CWRS Wheat

Two lines from the 2007 Western Bread Wheat Cooperative Test (**BW852 and BW854**) were advanced for Request of Support for Registration in February of 2008. BW854 was withdrawn on the first round of voting as it was objected to by 2 of the 3 WRT evaluation teams. BW852 was supported by the Agronomy ET, Not objected to by the Quality ET and objected to by the Disease ET. In the final vote, BW852 was defeated. Thus, no wheat lines were registered from this program in 2008.

Forty eight CDC hard red and hard white spring wheat lines were entered in six Cooperative or pre-coop tests in 2008.

Lines in the Final Year of Variety Registration Tests in 2008

Lines proposed for Support of Registration

Three CDC lines (**BW880, BW881** and **BW883)** from the WBWC Test were brought forward for Support of registration at the 2009 PRCWRT meeting in February, 2009. All three lines were supported.

The salient points of these candidate cultivars are presented below.

BW880 was selected from the cross W95132/AC Barrie made at the University of Saskatchewan in the winter of 1998.

The pedigree of W95132 is CDC Teal//EE8/Kenyon#35. The parental line W95132 was selected from the cross CDC Teal//EE8/Kenyon#35 made in 1990. EE8/Kenyon is a winter x spring wheat cross made as part of a Ph.D. project studying the transfer of leaf disease resistance to spring wheat (H. Ma, 1993). F3-derived F4 family seedlings of EE8/Kenyon were screened for *S. nodorum* under controlled conditions. Plants from one of the most resistant spring growth habit F4 families (no.35) were crossed on to CDC Teal. W95132 was evaluated in the 1997 WBWB Test as code 27.

The resulting F1 from the cross W95132/AC Barrie was grown in a summer crossing shelter at Saskatoon in 1998. The F2 was grown as a bulk at Saskatoon in 1999 and as an F3 bulk in a winter nursery. The F4 generation was grown as a space-planted bulk at Saskatoon in 2000. Seed from an F4 single-plant selection was grown in a rust nursery at Saskatoon in 2001 as an F5 hill and selected on the basis of rust reaction, plant type and straw strength. The process was repeated in 2002. BW880 is derived from a bulked F6 head-row. The F7 was grown in an unreplicated yield trial nursery at Saskatoon in 2003 and selected on the basis of yield under drought conditions. BW880 was evaluated as W04086 in local yield tests (four trials) in 2004 and in the Western Bread Wheat 'B' test in 2005 as code #45. BW880 was subsequently evaluated in the Western Bread Wheat Cooperative Test from 2006 to 2008.

AREA OF ADAPTATION: Spring wheat growing regions of western Canada.

STRENGTHS: Increased yield coupled with good straw strength, resistance to rust, improvement in leaf spot infection level, FHB similar to AC Barrie and Katepwa.

WEAKNESSES: Smaller seed mass.

DESCRIPTION: BW880 is a standard height, awnless, hollow-stemmed wheat with high yield potential (Table 1). In three years of testing in the Western Bread Wheat Cooperative Test, BW880 was 15.8, 1.9, 10.6 and 12.3% higher yielding than Katepwa, AC Superb, Laura and AC Barrie, respectively. BW880 yielded 17.4% higher than Lillian. BW880 had lower lodging scores than the check cultivars and had shorter straw than all the checks except Superb (Table 1). BW880 was similar in days to maturity to AC Barrie. BW880 had an intermediate test weight but lower kernel weight, being similar to Laura in that aspect (Table 1).

BW880 gave moderately resistant to intermediate reactions to prevalent races of leaf rust and an over-all resistant reaction to stem rust. Reaction to loose smut was MR or R. BW880 gave variable reactions to bunt, ranging from I to VS. Leaf spotting disease levels were, on average, similar to the best check, Lillian. The FHB reactions for BW880 ranged from MR to MS. The average FHB Disease index for BW880 was 29% compared to 25, 31, 33, 25 and 54% for Katepwa, Superb, Laura, AC Barrie and Lillian, respectively. DON levels from grain produced in FHB inoculated nurseries were, on average, equal to the best checks, Katepwa and AC Barrie.

BW881 was selected from the cross CDC Bounty/FHB4 made at the University of Saskatchewan during the fall of 1999.

The parental line FHB4 is a doubled haploid line developed by the Crop Development Centre and has the pedigree CDC Teal*2/ND2710. The parental line FHB4 was selected on the basis of its reaction to Fusarium head blight in the 1999 Carman FHB inoculated nursery (University of Manitoba).

The resulting F1 from the cross CDC Bounty/FHB4 was grown in the greenhouse during the winter of 1999/2000. The F2 was grown as a bulk at Saskatoon in 2000 and as an F3 bulk in a winter nursery. The F4 generation was grown as a space-planted bulk at Saskatoon in 2001. Seed from an F4 single-plant selection was grown in a rust nursery at Saskatoon in 2002 as an F5 hill and selected on the basis of rust reaction, plant type and straw strength. Seed from a single F5 spike was grown in a head row in the 2002/2003 winter nursery. BW881 is derived from a bulked F6 head-row. The F7 was grown in a two replicate yield trial nursery at Saskatoon in 2003 and selected on the basis of yield under drought conditions. BW881 was evaluated as W03602 in local yield tests (three trials) in 2004 and in the Western Bread Wheat 'B' test in 2005 as code #33. BW881 was subsequently evaluated in the Western Bread Wheat Cooperative Test from 2006 to 2008.

AREA OF ADAPTATION: Spring wheat growing regions of western Canada.

Table 1. Agronomic data for BW880 and check cultivars in the Western Bread Wheat Cooperative Test, 2006 to 2008

	Yield (Kilograms hectare^{-1})										Maturity (days)	Height (cm)	Lodging (1-9)
	zone 1			zone 2			zone 3						
Entry	**2006**	**2007**	**2008**	**2006**	**2007**	**2008**	**2006**	**2007**	**2008**	**2006-08**	**2006-08**	**2006-08**	**2006-08**
Katepwa	2425	2400	2885	3430	3294	4205	5004	4110	5840	3742	97.5	101.1	3.1
Superb	2529	2966	3566	3543	3834	4898	5619	4474	6987	4250	100.8	90.3	2.1
Laura	2009	2283	3270	3690	3281	4532	5526	4374	5990	3916	100.0	100.4	3.8
Barrie	2663	2586	2905	3299	3453	4192	5547	4605	6305	3859	98.6	97.3	2.1
Lillian	2165	2435	3165	3371	3239	4072	5032	4166	5748	3689	98.8	96.9	3.1
BW880	**2718**	**2660**	**3372**	**4038**	**3863**	**4630**	**6542**	**5167**	**6497**	**4332**	**98.9**	**94.5**	**1.7**
Stations	1	2	2	7	9	9	2	2	2	36	33	38	10
LSD	317	379	363	263	201	286	684	882	978	246	1.2	2.6	0.8

	Test weight (kg hL-1)	Kernel weight (mg)	Protein (%)
Entry	**2006-08**	**2006-08**	**2006-08**
Katepwa	78.4	32.0	14.9
Superb	79.5	38.2	14.7
Laura	79.0	31.9	15.0
Barrie	79.6	33.8	15.2
Lillian	78.1	35.0	16.3
BW880	**78.5**	**31.5**	**15.2**
Stations	37	37	37
LSD	0.6	1.1	0.4

STRENGTHS: Increased yield.

WEAKNESSES: Similar in height to taller checks.

DESCRIPTION: BW881 is a standard height, awned, hollow-stemmed wheat with high yield potential (Table 1). In three years of testing in the Western Bread Wheat Cooperative Test, BW881 was 13.0, 7.9 and 9.5% higher yielding than Katepwa, Laura and AC Barrie, respectively but 0.6% lower yielding than Superb. BW881 yielded 14.6% higher than Lillian. BW881 was similar to Laura and Katepwa straw length with intermediate lodging scores (Table 1). BW881 was intermediate for days to maturity. BW881 had an average test weight similar to that of AC Barrie and Superb with a kernel weight within the range of the check cultivars.

BW881 gave moderately resistant to intermediate reactions to prevalent races of leaf rust and an over-all resistant reaction to stem rust. Reaction to loose smut was R. BW881 gave an intermediate reaction to bunt. Leaf spotting disease levels were, on average, similar to the intermediate checks. The FHB reactions for BW881 ranged from MR to MS. The average FHB Disease index for BW881 was 26% compared to 25, 31, 33, 25 and 54% for Katepwa, Superb, Laura, AC Barrie and Lillian, respectively. DON levels from grain produced in FHB inoculated nurseries were, on average, lower than the best checks, Katepwa and AC Barrie.

BW883 was selected from the cross AC Elsa//CDC Teal/Seneca DH#10 made at the University of Saskatchewan during the fall of 1998.

The parental line CDC Teal/Seneca DH#10 is a doubled haploid line developed by the Crop Development Centre and selected on the basis of its phenotypic resistance reaction to the orange wheat blossom midge (*Sitodiplosis mosellana*). The winter wheat cultivar Seneca is a carrier of the Sm1 gene.

The resulting F1 from the cross AC Elsa//CDC Teal/Seneca DH#10 was grown in the greenhouse during the winter of 1998/1999. The F2 was grown as a bulk at Saskatoon in 1999 and as an F3 bulk in a winter nursery. The F4 generation was grown as a space-planted bulk at Saskatoon in 2000. Seed from an F4 single-plant selection was grown in a rust nursery at Saskatoon in 2001 as an F5 hill and selected on the basis of rust reaction, plant type and straw strength. The process was repeated in 2002. BW883 is derived from a bulked F6 head-row. The F7 was grown in an unreplicated yield trial nursery at Saskatoon in 2003 and selected on the basis of yield under drought conditions. BW883 was evaluated as W04112 in local yield tests (three trials) in 2004 and in the Western Bread Wheat 'B' test in 2005 as code #51. BW883 was subsequently evaluated in the Western Bread Wheat Cooperative Test from 2006 to 2008.

Spring wheat growing regions of western Canada outside of the high incidence risk area for FHB.

STRENGTHS: High yield coupled with good straw strength, midge resistant.

WEAKNESSES: MS to S reaction to FHB.

DESCRIPTION: BW883 is a standard height, awnless, hollow-stemmed wheat with high yield potential (Table 1). In three years of testing in the Western Bread Wheat Cooperative Test, BW883 was 19.1, 4.8, 13.8 and 15.4% higher yielding than Katepwa, AC Superb, Laura and AC Barrie, respectively. BW883 yielded 20.8% higher than Lillian. BW883 had average lodging scores equal to Superb and AC Barrie and had shorter straw than all the checks except Superb (Table 1). BW883 had an average test weight similar to that of AC Barrie and Superb with a kernel weight within the range of the check cultivars.

BW883 gave a resistant reaction to prevalent races of leaf rust and reactions to stem rust ranging from VR to I. Reaction to loose smut was I to MS. BW883 gave reactions to bunt, ranging from I-MS to S. Leaf spotting disease levels were, on average, within the range of the checks. The FHB reactions for BW883 were MS in two years of testing and S in 2007. The average FHB Disease index for BW883 was 38% compared to 25, 31, 33, 25 and 54% for Katepwa, Superb, Laura, AC Barrie and Lillian, respectively. DON levels from grain produced in FHB inoculated nurseries were, on average, equal to those of Superb, the check with the highest average value.

Midge damage levels in BW883 were significantly lower than in McKenzie, Harvest and Snowbird.

A fourth CDC line (**PT575**) from the Parkland Cooperative Test was brought forward for Support of registration at the 2009 PRCWRT meeting in February, 2009. This line was supported for registration.

PT575 was selected from the cross CDC Bounty/CDC Imagine made at the University of Saskatchewan in 1999. PT575 carries the Imidazolinone-tolerance gene present in CDC Abound and CDC Imagine. The herbicide Imazamox was used as the selection agent at a rate of 40g ai/ha in the selection of PT575 in the F2, F4, F5 and F6 generations.

The F1 from the cross CDC Bounty/CDC Imagine was grown in the greenhouse during the winter of 1999/2000. The F2 was grown as a bulk at Saskatoon in 2000 and as an F3 bulk in a winter nursery. The F4 generation was grown as a bulk at Saskatoon in 2001. Seed from an F4 single-plant selection was grown in a rust nursery at Saskatoon in 2002 as an F5 hill and selected on the basis of rust reaction, plant type and straw strength. PT575 is derived from a bulked F5 head-row. The F6 was grown in an unreplicated yield trial nursery at Saskatoon in 2003 and selected on the basis of yield. PT575 was evaluated as IR04031 in local yield tests (five trials) in 2004 and in the Western Bread Wheat 'B' test in 2005 as code #53. PT575 was subsequently evaluated in the Parkland Wheat Cooperative Test from 2006 to 2008.

AREA OF ADAPTATION: Spring wheat growing regions of western Canada outside of the high incidence risk area for FHB.

STRENGTHS: Higher yield coupled with intermediate maturity.

WEAKNESSES: MS to I reaction to FHB.

DESCRIPTION: PT575 is a standard height, awnless, hollow-stemmed wheat with higher yield potential than the agronomic checks. In three years of testing in the Parkland Wheat Cooperative Test, PT575 was 9.2, 3.7, 6.4 and 4.6% higher yielding than Katepwa, CDC Teal, AC Barrie and AC Splendor, respectively. PT575 had average lodging scores similar to the best check, AC Barrie with a straw length that was intermediate. PT575 was intermediate in maturity; between CDC Teal and AC Barrie. PT575 had an average test weight equal to the best check, AC Barrie with a kernel weight within the range of the check cultivars.

PT575 gave a reaction to prevalent races of leaf rust ranging from MR to MS and reactions to stem rust ranging from R to I. PT575 was tested (10 seedlings) using the molecular markers diagnostic for Lr34. PT575 carries the R allele for the swm10 and CslvMS1 markers.

Reaction to loose smut was R or MR. PT575 gave reactions to bunt, ranging from MR to I-. The FHB reactions for PT575 were MS or I). The average FHB Disease index for PT575 was 39% compared to 24, 55, 20, and 33% for Katepwa, CDC Teal, AC Barrie and AC Splendor, respectively. A single data point for DON from grain produced in an FHB inoculated 2008 nursery indicated an intermediate level for PT575.

Table 2. Agronomic data for BW881 and check cultivars in the Western Bread Wheat Cooperative Test, 2006 to 2008

	Yield (Kilograms hectare^{-1})										Maturity (days)	Height (cm)	Lodging (1-9)
	zone 1			zone 2			zone 3						
Entry	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006-08	2006-08	2006-08	2006-08
Katepwa	2425	2400	2885	3430	3294	4205	5004	4110	5840	3742	97.5	101.1	3.1
Superb	2529	2966	3566	3543	3834	4898	5619	4474	6987	4250	100.8	90.3	2.1
Laura	2009	2283	3270	3690	3281	4532	5526	4374	5990	3916	100.0	100.4	3.8
Barrie	2663	2586	2905	3299	3453	4192	5547	4605	6305	3859	98.6	97.3	2.1
Lillian	2165	2435	3165	3371	3239	4072	5032	4166	5748	3689	98.8	96.9	3.1
BW881	**2803**	**2559**	**3285**	**4067**	**3556**	**4495**	**6329**	**4801**	**7044**	**4227**	**99.6**	**100.1**	**2.4**
Stations	1	2	2	7	9	9	2	2	2	36	33	38	10
LSD	317	379	363	263	201	286	684	882	978	246	1.2	2.6	0.8

Entry	Test weight (kg hL-1) 2006-08	Kernel weight (mg) 2006-08	Protein (%) 2006-08
Katepwa	78.4	32.0	14.9
Superb	79.5	38.2	14.7
Laura	79.0	31.9	15.0
Barrie	79.6	33.8	15.2
Lillian	78.1	35.0	16.3
BW881	**79.5**	**35.0**	**15.2**
Stations	37	37	37
LSD	0.6	1.1	0.4

Table 3. Agronomic data for BW883 and check cultivars in the Western Bread Wheat Cooperative Test, 2006 to 2008

	Yield (Kilograms hectare^{-1})										Maturity (days)	Height (cm)	Lodging (1-9)
	zone 1			zone 2			zone 3						
Entry	**2006**	**2007**	**2008**	**2006**	**2007**	**2008**	**2006**	**2007**	**2008**	**2006-08**	**2006-08**	**2006-08**	**2006-08**
Katepwa	2425	2400	2885	3430	3294	4205	5004	4110	5840	3742	97.5	101.1	3.1
Superb	2529	2966	3566	3543	3834	4898	5619	4474	6987	4250	100.8	90.3	2.1
Laura	2009	2283	3270	3690	3281	4532	5526	4374	5990	3916	100.0	100.4	3.8
Barrie	2663	2586	2905	3299	3453	4192	5547	4605	6305	3859	98.6	97.3	2.1
Lillian	2165	2435	3165	3371	3239	4072	5032	4166	5748	3689	98.8	96.9	3.1
BW883	**3135**	**2730**	**3317**	**4211**	**3974**	**4703**	**6673**	**5082**	**6782**	**4455**	**97.6**	**94.2**	**2.1**
Stations	1	2	2	7	9	9	2	2	2	36	33	38	10
LSD	317	379	363	263	201	286	684	882	978	246	1.2	2.6	0.8

Entry	**Test weight (kg hL-1) 2006-08**	**Kernel weight (mg) 2006-08**	**Protein (%) 2006-08**
Katepwa	78.4	32.0	14.9
Superb	79.5	38.2	14.7
Laura	79.0	31.9	15.0
Barrie	79.6	33.8	15.2
Lillian	78.1	35.0	16.3
BW883	**79.5**	**33.3**	**14.8**
Stations	37	37	37
LSD	0.6	1.1	0.4

2008-2009 Breeding Program (CWRS, CWHW)

Approximately 400 spring wheat lines (across market classes) were in the final stages of CDC in-house testing in 2008. These lines were tested in trials each planted at up to 5 sites. This was done in part with WGRF and BASF funding and in-kind support from SWP. The pre-Coop replicated yield tests totaled 5,800 plots.

In the second level of testing, 900 lines were evaluated in a series of 2-rep tests at single sites for a total of 1800 plots. Circa 8,000 springs wheat lines were evaluated in EGWYT yield trials at Saskatoon in 2008. Nearly 100,000 F4/F6 lines were grown in rust nurseries or irrigated sites in 2008 (SAF&WGRF, BASF funding). This was an increase of 30% over 2007.

We evaluated approximately 990 wheat populations in the F2-F4 generations. A majority of this material was grown in solid-seeded bulk plots. A series of new (n=145) populations were initiated during the reporting period.

Lines in Years 1 and 2 of 2008 Variety Registration Tests

There were no second year entries in the 2008 WBWC test (from any programs).

Of the four 1st year CDC entries in the 2008 WBWC Test, one (**BW908**) was advanced.

The two 2nd year CDC entries in the 2008 CBWC (**BW421** and **BW423**) have been advanced for a third year of testing in 2009. Both lines continue to have promising reactions to FHB. None of the three 1st year entries **(BW438, BW439, and BW440)** were advanced.

The lone 2nd year CDC entry (PT577) in the 2008 Parkland Cooperative Test was dropped due low yield. The two 1st year lines **(PT579, PT580)** were both advanced for further testing in 2009.

There were no CDC entries in the 2008 Hard White Wheat Registration Test. One line was advanced from the 2008 CHWB test to the 2009 HW Registration Test (as **HW612**).

One CWES line (**ES112**) was entered in the 2008 HY Wheat Registration Test but not advanced due to poor quality.

Lines selected from the WBW 'B' Test for advancement

The CDC spring wheat breeding program coordinates the Western Bread Wheat 'B' Test. This is one of two pre-cooperative tests used to identify CWRS wheat breeding lines for entry into bread wheat Registration Tests in western Canada. In 2008 the WBWB consisted of 56 entries and was planted at seven sites across western Canada. The CDC, AAFC-SPARC and UofA contributed entries to the test. Of the 52 experimental lines, 22 were from the CDC. Of the 22 lines, seven were retained for proposed entry in the 2009 CBWC, WBWC or Parkland C tests (Table 4).

Table 4. Summary table for 2008 Western Bread Wheat B Test

			Yield	Maturity	Height	ldg 1 -	Test wt.	K.wt.	Bunt		Cmn FBH VRI
ENTRY	NAME		%Barrie	days	cm	9	kg/hL	mg	%	rxn	%
1	AC Barrie	Pedigree	**100.0**	100.3	88.0	1.0	80.4	37.0	19	I-	6
2	Superb		**116.6**	102.3	85.6	1.0	80.6	41.8	4	VR	38
3	AC Elsa		**106.4**	99.9	88.3	1.0	79.2	34.7	19	I-	56
4	Lillian		**104.5**	100.5	89.3	4.7	78.9	36.8	12	MR	43
32	W06317	W00703/BW282	**105.1**	99.8	86.8	1.0	80.3	36.8	22	I	29
38	W07028	282/99FHB359	**113.2**	99.5	82.6	2.3	79.8	36.3	41	MS	9
41	W07090	BW 282/BW781	**106.1**	100.4	82.1	1.0	81.0	34.1	15	MR	38
42	W07097	BW 282/BW781	**103.5**	99.8	85.7	1.4	80.9	34.7	16	MR	25
43	W07108	BW 282/BW781	**113.1**	99.1	84.3	1.0	80.9	36.1	26	I	64
45	W07127	BW 282/BW781	**106.4**	100.1	83.5	1.0	81.0	34.5	18	I-	27
47	W07145	BW 282/BW781	**109.3**	99.9	82.9	1.0	80.8	35.9	23	I	12
	# of sites		7	7	7	1	7	7			

Between 22 and 26 new CDC lines will be entered in 2009 pre-Registration ('B'-level) Tests.

Spring Spelt and other Alternative Wheats Project (ADF)

The spring spelt line **03SPELT4** was supported for Registration in February 2009.

03SPELT4 was selected from the cross RL5407/Common winter spelt (F5)//PGR8801. RL5407 is an awned, grey-black hulled spring spelt accession similar to CDC Nexon in agronomic profile. PGR8801 is a spring habit; white hulled spring spelt accession from the Plant Gene Resources Centre of Canada collection. During the winter of 1997/1998 progeny from a single spike selection from an F5 head row of the cross RL5407/Common winter spelt, grown in 1997, were used in the cross with PGR8801. The F5 head row is a sister-line of the cultivar CDC Zorba.

The F1 generation was grown in the field in 1998. The F2 and F3 generations were grown in bulk plots at Saskatoon during the 1999 and 2000 crop seasons, respectively. F3-derived F4 head rows were grown in a dryland nursery in 2001. 03SPELT4 is derived from one of those bulked F_4 head rows. The F4 rows were selected on the basis of earlier heading relative to CDC Nexon, lack of awns, reduced height and lodging. The candidate line was evaluated in an unreplicated yield plot nursery in 2002 and selected using the same criteria as in 2001, with the addition of yield, grain protein concentration and SDS sedimentation volume. 03SPELT4 was subsequently evaluated in local yield tests in 2003 at three sites and in and in the Private Spring Spelt Wheat Test from 2004 to 2008.

AREA OF ADAPTATION: Longer crop season wheat growing areas of Saskatchewan and Alberta.

STRENGTHS: Increased yield coupled with earlier maturity, stronger straw and higher grain protein content. Lack of awns will facilitate grain handling and processing. Higher grain protein content. Intermediate reaction to FHB.

WEAKNESSES: Those inherent to spelt wheat.

DESCRIPTION: 03SPELT4 spring spelt is awnless, hollow-stemmed with earlier maturity than the spelt check cultivar CDC Nexon. Based on 38 site-years of data from the Private Spring Spelt Wheat Test, 03SPELT4 was 28 and 8% higher yielding (hull on basis) than CDC Nexon and CDC Zorba, respectively. 03SPELT4 was shorter-strawed and less prone to lodging than CDC Nexon and CDC Zorba. 03SPELT4 was earlier maturing than CDC Nexon but a day later maturing than CDC Zorba. 03SPELT4 was similar to CDC Nexon and CDC Zorba for test weight and kernel weight. The threshability of 03SPELT4 was lower than that of CDC Nexon and CDC Zorba. The threshability of 03SPELT4 is similar to that of winter spelt cultivars. 03SPELT4 had a higher grain protein concentration than either CDC Nexon or CDC Zorba.

03SPELT4 gave an intermediate reaction to prevalent races of leaf rust but was susceptible to stem rust. 03SPELT4 was resistant to loose smut and bunt. The average (n=6 trials) FHB index for 03SPELT4 was similar to that of CDC Zorba and 10% units higher than CDC Nexon.

03SPELT4 has a soft red kernel and weak gluten characteristics desired for spelt wheat marketing.

Acknowledgement of Independent Test Cooperators

Dr. A. Brule-Babel (University of Manitoba), Dr. R.M. DePauw (AAFC-SPARC), Dr. D. Salmon (AFCDC-Lacombe), Mr. Steve Dueck (AAFC-Scott), Dr. Dean Spaner (University of Alberta).

The Spring Spelt Private Coop Test was coordinated by this Program in 2008. The line 04SPELT48 was tested for a 3rd year and continues to be earlier maturing than the spring spelt check cultivars. We will advance this line, along with 04SPELT49 for a 4th year of testing in 2009.

Progress was made in advancing breeding material for each of the three hulled species (spelt, einkorn and emmer). Emmer accessions were evaluated in both replicated and unreplicated trials in 2008. Low yield and weak straw continue to be a limiting factor in the introduced accessions. Lines developed from a cross with 'Vernal' were first yield-tested in 2008.

Approximately 300 lines from two spring spelt populations were grown in unreplicated trials in 2007. Of those, nine were retained for testing in 2008. These 08SPELT series lines were evaluated at three sites. All lines were similar to, or higher yielding than, CDC Zorba with equal to or earlier days to head and maturity. Most of the lines were shorter-strawed than CDC Zorba. Three of the lines (entries 6,7 and 8) were culled on the basis of poorer stem rust reactions. Two of the lines appeared to have stem rust reactions similar to AC Barrie. The remaining lines were evaluated for quality. Two years of quality data indicates that the 08SPELT lines have gluten strength characteristics suitable for the spelt market and have Falling Number values that are intermediate between CDC Zorba and the best check (04SPELT48).

Nearly 60 spring spelt populations ranging from the F1 to F5 generation were advanced a generation in 2008. One population (X03.68) will be evaluated in unreplicated trials in 2009.

Table 5 Summary of 2008 Agronomic and disease data for the spring spelt wheat registration test

ENTRY		Grain Yield kg/ha	% CDC Nx	Heading days	Maturity days	Height cm	Lodging 1 to 9	T.wt kg/hL	K.wt mg	Thresh. %	Grain Protein %
1	AC Barrie	4403	**107.4**	64.4	100.3	91.0	2.5	80.4	36.4	98.6	16.6
2	CDC Nexon	4099	**100.0**	71.8	106.2	121.4	7.3	78.1	39.8	46.3	14.9
3	CDC Zorba	4661	**113.7**	70.9	105.1	121.8	4.3	77.0	38.9	42.6	15.8
4	03SPELT4	5183	**126.5**	70.0	105.7	119.2	4.0	77.0	39.0	16.3	16.5
5	04SPELT48	4964	**121.1**	67.0	103.6	111.1	3.8	79.1	37.7	31.9	16.1
6	04SPELT49	4971	**121.3**	66.9	103.8	114.1	4.5	79.0	39.4	32.3	16.2
	# of sites	8		5	6	8	4	8	8	8	8

Emmer lines from the USDA and Gatersleben collection were initially grown out in two nurseries in 2007. The first group of accessions was previously evaluated in 1995-1996. At that time more emphasis had been placed on end-use quality. Of the 103 emmer accessions grown in the 2007 unreplicated plot nursery, 32 were re-tested in a replicated trial at two sites in 2008. The lines differed in stand establishment despite the seed having been hand-picked after dehulling. Grain yield was correlated with stand (r=0.75**) and days to heading (r=0.74**). Most of the emmer lines were earlier heading than the control, 'Vernal', earlier maturing and shorter-strawed. However, all of the lines were lower-yielding than Vernal. These results are similar to those we obtained in 1995-1996. We tested the emmer lines in the bunt and rust nurseries in 2008. With the exception of Vernal, most of the lines were susceptible to common bunt. This was rather unexpected as durum (a relative of emmer) is generally highly resistant to the pathogen and one might have assumed that emmer would behave in the same manner. The emmer lines varied in terms of their reactions to both leaf and stem rust. Based on the bunt reactions, only 3 or 4 lines will be advanced for field evaluation in 2009.

The second group of accessions(n=300) was first evaluated in a hill plot nursery in 2007. This set of accessions had not been tested by us for adaptation or agronomic performance in the past. In 2007 a total of 111 accessions were harvested after culling on the basis of maturity, height and spike shattering (disarticulation) and retested in unreplicated micro-plots in 2008. Of the 111 accessions, 29 were retained after culling on the basis of straw strength, plant height and grain yield. A number of these lines will be re-tested in a replicated trial in 2009.

The emmer population from the cross Vernal/97Emmer19 was advanced to the F4 generation in 2007. Of the 700 or so lines, 460 were advanced and grown in an unreplicated trial format in 2008. Since emmer is quite weak-strawed, the yield nursery was culled for lodging on three separate occasions in 2008. After culling on the basis of lodging, height and grain yield, 158 lines remain. The objective is to cull these lines further to 120 or so and retest them in a replicated trial format in 2009. At this point this breeding material appears to hold more promise than direct accession selection for developing an adapted cultivar.

A backcross was made to Vernal and that material was grown in the F2 and F3 generations in 2008. This population is being advanced two generations in the greenhouse during the winter of 2008/2009 and F6 hills will be grown in the field in 2009. The backcross to Vernal should allow us to recover some resistance to bunt and combine that trait with the earlier maturity of 97Emmer19. A number of spring x winter emmer crosses were made and the F1 grown out in the greenhouse.

In the case of einkorn wheat we had two populations in the F7 generations grown in unreplicated micro-plot (1 x 1.3 m) format in 2008. These two populations represent the last of the low lutein material and we are hoping to identify higher-yielding freer-threshing lines for use as parental material.. Of the 459 lines planted, 94 were retained for yellow pigment evaluation and 33 will be grown in a replicated trial in 2009.

F6 hills from three populations (X03.70 to 72) that were less prone to lodging and spike shattering were harvested in 2008 and will be evaluated in unreplicated trials in 2009. These three populations represent the first of the material developed for the selection of improved lutein content and baking quality.

CWHW Wheat Germplasm Improvement Project (ADF, WGRF)

As part of our hard white wheat development program funded by WGRF and ADF we evaluated 38 experimental lines at five sites in 2008. Of the 38 line, 25 were culled on agronomic performance and disease reaction. Six lines remained after culling on protein content. Five lines were retained for more detailed quality evaluation and only one survived the process. The lone surviving line was culled on the basis of poor grain color (reddish appearance). Thus, no lines were advanced into the Cooperative testing system. We anticipate having a 64 entry multi-location CWHW test in 2009.

The CDC spring wheat breeding program requires a NaOH or KOH protocol that will differentiate between red and white pericarp grain, but will not affect viability. Although published NaOH and KOH protocols are effective in differentiating red from white pericarp grain, they leave the grain unsuitable for use in machines such as color sorters and seeders. As well, the published NaOH and KOH protocols reduce germination and may negatively impact crop growth. In 2008 we evaluated reduced volumes of 5% NaOH and KOH on red and white pericarp grain to see if we could still achieve color differentiation without negatively impacting germination and crop growth. Color differentiation could be measured with all of the reduced volume treatments using the Hunter Lab a* value. The L* and b* values were found to be less suitable for detecting color differentiation. As the volume of salt increased, there was a decrease in germination. Three treatments (1.0 ml NaOH, 1.0 ml KOH, and 1.5 ml KOH) were able to differentiate red pericarp wheat from white pericarp wheat without reducing germination below 50%. Hence these treatments were further tested in the field to determine if they have any negative effects on crop growth. The salt treatments had no effect on emergence, days to heading, and days to maturity, height, yield, seed weight or test weight. Seedling density was reduced by the salt treatments with the 1.5 ml KOH treatment having the lowest seedling density (17.4 seedlings /quadrat) while the 1.0 ml NaOH and 1.0 ml KOH treatments were not significantly different from one another (19.9 and 19.7 seedlings /quadrat respectively; LSD = 1.17) and had a seedling density that was lower than the untreated control (21.8 seedlings

/quadrat). Either the 1.0 ml NaOH or the 1.0 ml KOH treatments would be suitable for use in a breeding program selection scheme.

The breeding program continued to have success using the Satake ScanMaster II color sorting machine and continued to color sort F2 to F4 bulk populations (n=150) segregating for red and white pericarp grain.

Backcross derived lines selected for two major FHB QTL (3BS and 5AS) were evaluated for FHB reaction in 2008. In five of the six populations there was evidence of significant improvement in FHB reaction relative to the recurrent parent. The FHB VRI means for the five populations were 1.5 to 4 times lower than their recurrent parents. These results are very encouraging but will need to be verified in 2009.

Canaryseed Development Breeding and Research Project (ADF, CDCS)
The Canaryseed Development Commission of Saskatchewan (CDCS) initiated funding canaryseed breeding initiatives at the CDC effective July 2008 with signing of a multi-year agreement.

The 2008 Glabrous canaryseed registration test was successfully grown at five sites. The results from that trial are summarized in Table 6. The brown seeded line C00038 continued to perform well. In 2008, C00038 out-yielded C05004 and performed equal to the latter line over three years of testing. Since we already have developed breeder seed of C00038 we will drop C05004 from, further testing. The two yellow-seeded lines (C05041 and C05091) that we increased for eventual food research purposes were amongst the highest yielding lines (Table 6). Four other replicated trials were conducted in 2008. Ten lines were selected from a total of 124 evaluated at two sites in 2008.

Approximately 1,000 glabrous lines were evaluated in unreplicated yield trials at Kernen in 2008. Approximately 3,600 lines were grown in F4 or F5 hills in 2008. Half of the hills were selected and lines will be grown in unreplicated trials and paired hills in 2009.

Table 6. 2008 Glabrous canaryseed Registration Test - Summary Table

ENTRY	NAME	Yield kg/ha	% Maria	Heading days	Maturity days	Height cm	Test wt. kg/hL	Seed wt. mg	seed
1	CDC Maria	1863	**100.0**	52.1	94.1	89.2	71.2	7.88	GB
2	C99005	1918	**103.0**	52.6	93.9	91.3	72.2	8.19	GY
3	CDC Bastia	2092	**112.3**	52.7	94.3	90.5	72.0	8.01	GB
4	CDC Togo	1987	**106.6**	53.3	94.4	91.3	71.0	8.64	GB
5	C00038	2204	**118.3**	53.1	94.2	87.5	70.7	7.92	GB
6	C03087	2312	**124.1**	53.8	96.0	96.6	72.2	8.57	GY
7	C04035	2230	**119.7**	54.1	95.6	98.5	72.2	8.37	GY
8	C05004	2108	**113.1**	52.2	93.7	88.0	69.5	7.90	GB
9	C05028	2272	**122.0**	52.2	96.6	86.7	71.3	8.79	GY
10	C05041	2290	**122.9**	53.1	95.2	85.0	72.1	8.32	GY
11	C05046	2164	**116.1**	52.1	95.7	89.2	72.1	8.64	GY
12	C05070	2086	**112.0**	53.4	94.8	85.8	71.7	8.12	GY
13	C05082	2117	**113.6**	52.1	95.7	89.3	71.2	8.73	GY
14	C05090	2063	**110.7**	51.8	95.3	92.4	72.4	8.36	GY
15	C05091	2229	**119.7**	52.4	95.5	88.6	71.1	8.46	GY
16	C06003	2150	**115.4**	53.5	94.8	87.3	71.6	8.17	GY
	# Sites	5		3	3	5	5	5	

A SADF canaryseed research project was initiated in early 2008. Three areas of research are being addressed (canaryseed hybridization, pathology and molecular marker development).

The use of Surf Excel (SE) as a chemical hybridizing agent (CHA) met with limited success in 2008, despite our attempts to fine-tune plant staging and SE concentrations. Pollen sterility did not exceed 20%. In 2009 we will attempt (1) root feeding with GA3 at different concentrations instead of foliar application (2) injecting GA3 with a syringe into the boot or leaf sheath 10 days prior flowering and (3) spraying with 150 ppm GA3 on the florets one day prior to anthesis (this is a repeat of the 2008 preliminary experiment).

The initial objective for the canaryseed leaf mottle pathology subproject was to develop controlled environment protocols for inoculating and rating canaryseed with *S. tritici*. The protocols were appropriate for *S. triseti* and will be used in future experiments.

The first year's objective for the molecular marker subproject was to conduct extensive investigations to explore the cross applicability and transferability of available microsatellite markers to canaryseed. Results clearly demonstrated that only a limited number of barley microsatellites or wheat unigene SSR could amplify DNA products of expected size from canary seed DNA. In the case of markers that showed DNA products of expected size, no polymorphism could be observed using agarose gel or very sensitive DNA-sequencing gel techniques. Therefore, based on the results of current study and those in a previous ADF project, it is safe to conclude that there are very limited chances of success in transferring available cereal microsatellite markers to canary seed.

Spring wheat cultivars for organic production project (SADF)

This project was completed at the end of 2008. The primary objective of this research was to determine whether western Canadian spring wheat (*Triticum* sp) cultivars and advanced generation breeding lines differ in their ability to compete against model weeds. A total of 48 wheat cultivars were grown in the absence or presence of simulated weed competition conditions over a three year period. Weeds consisted of cultivated oat (*Avena sativa*) and oriental mustard (*Brassica juncea*). Significant (P=0.01) weed by cultivar interactions involving changes in cultivar rank were detected for wheat grain yield. The highest yielding cultivars under weed-free conditions were not necessarily the highest yielding under weedy conditions. Cultivars which suffered smaller yield reductions were more effective in limiting oat and mustard grain yields. During the course this project 274 advanced generation bread wheat breeding lines from the CDC were evaluated at least once. Of these 274 lines, two were evaluated for competitive ability for three years and, in parallel, entered in cultivar registration tests. One of these lines W03602 (BW881) was brought forward for Support of Registration and supported. Over-all, however, cultivars and breeding lines selected in the absence of weed pressure appear to provide little scope for selecting more competitive cultivars that might be of use in organic production systems. Experimental lines developed under model weed pressure using divergent selection will provide a tool to assess the effectiveness of developing spring wheat germplasm that might be better suited to organic or reduced input production scenarios.

Enhancing Fusarium Head Blight Resistance in Spring and Durum Wheat Using Novel Approaches (ADF)

Three major QTL for fusarium head blight resistance were backcrossed to CDC Go, CDC Osler and CDC Alsask spring wheat by the Fall of 2008. The BC3 (*4) F1 plants are being grown out at the time of reporting. Selected near-homozygous BC_1F_3-derived spring wheat x *A. repens* progeny were evaluated for FHB reaction in three inoculated field nurseries in 2008. Twelve of the 16 lines that were retested in 2008 had lower FHB VRI scores (desirable) than the intermediate control, AC Cora. The remaining 10 to 12 lines from this group will be retained for replicated testing in 2009. Another series of 52 intergeneric lines were field-tested for the first time in 2008. Two-thirds of these lines had FHB reactions similar to Sumai3. We will retest these lines in 2009 to confirm their reactions. Populations from crosses to three promising intergeneric derivatives have been advanced several generations during this reporting cycle.

Undergraduate theses supervised

Analysis of selenium uptake in wheat, durum and lentil – Mark Carlson (Supervised by Curtis Pozniak; advisors; Dil Thavarajah, Bert Vandenberg and Pierre Hucl)

Listing of collaborations

Quality- related projects

Dr..ESM Abdel-Aal. AAFC, Guelph

Breeding-related in Canada

Dr. A. Brule-Babel, U. of Manitoba
Dr. D. Spaner, U. of Alberta
Drs. S. Fox, G. Humphreys and D. Brown, AAFC Winnipeg
Drs. R. DePauw, AAFC Swift Current
Dr. D. Salmon, FCDC, Lacombe
Mr. M. Etienne, Hyland Seeds
Ms. Kathy Hanson, Viterra
Mr. W. May, IHARF
Mr. E. Johnson, AAFC Scott
Semican, Que.
Mr. T. Huck Syngenta, Rosebank, MB

Overseas:

Dr. L. Talbert, Montana State Univ., Bozeman
Dr. T. Nakamura, MAFF, Japan

Sources of Funding

$ per annum:

P. Hucl, A. Vandenberg and 6 others. Enhancing nitrogen management through genetics in cereal-legume crop rotation. (WGRF) 2009-2012; $50,000

P. Hucl and D. Spaner. Selecting spring wheat for improved competitive ability - proof of concept. (SADF) 2009-2011; $64,000

P. Hucl, C. McCartney and R. Chibbar. Canaryseed hybridization protocol, disease resistance and DNA marker development. (SADF) 2008-2013; $95,000

P. Hucl and E. Abdel-Aal. Evaluation of high-pigment content wheat for antioxidant potential. (SADF) 2008-2011; $34,600

C. Pozniak, P. Hucl et al. Designer Cereal Grains for the Biofuels Industry. (SADF). 2008-2012

C. Pozniak, P. Hucl (ABIP) 2008-2011

P. Hucl and S. Shirtliffe. Ferality potential of seven Canadian crops (CSGA) 2008-2010; $4,600

P. Hucl and C. Perron. Development of hulled wheat varieties with improved agronomic and end-use traits. (SADF). 2007-2012; $53,000

P. Hucl, C. Pozniak, C. McCartney and D. Somers. Enhancing fusarium head blight resistance in spring and durum wheat using novel approaches. (SADF). 2007-2009; $85,000

P. Hucl and M. Matus-Cadiz. Hard White wheat improvement (SADF). 2005-2009; $60,000
P. Hucl. Spring wheat for Organic Production. (SADF). 2004-2009; $40,000.
P.Hucl. WGRF wheat check-off. 2005-2010. (net $150,000)
P. Hucl. BASF. CLEARFIELD spring wheat development Phase 2. 2003- (Confidential)

Outreach activity

Presentations

January 12, 2009. Canaryseed research update (CAC), Saskatoon

P. Hucl, D. Knievel and E.S.M. Abdel-Aal. Progress in developing and characterizing high-anthocyanin spring wheat. September 24, 2008. AACC, Honolulu, HI. (Invited speaker).

Committee membership

Dept. of PLSC - Field Experiments Committee, Member
Dept. of PLSC - Grain Quality Committee, Member
Dept. of PLSC - Variety Committee, Member
Dept. of PLSC - Graduate Student Committee, Chair
Coordinator Western Bread Wheat 'B' Test
Coordinator Spring Spelt Registration Test
Coordinator Glabrous canaryseed Registration Test
Member, PGDC
Member, SIA
Member, SACGC
Member, WGRF Technical Advisory Committee on Wheat
Member, Soils and Crops Organizing Committee
Advisor, Canaryseed Association of Canada
Member, SPG – R&D Committee
Member, IOC of the 11th International Wheat Genetics Symposium
Member, LOC of the 2009 IWQC

Refereed Publications

E.S.M. Abdel-Aal, A.A. Abou-Arab, T.H. Gamel, P. Hucl, C.J. Young, I. Rabalski,. 2008. Fractionation of Blue Wheat Anthocyanin Compounds and Their Contribution to Antioxidant Properties. Journal of Agricultural and Food Chemistry 56: 11171-11177.

M.A. Matus-Cadiz, C.J. Pozniak and P.J. Hucl. 2008. Puroindoline allele diversity in Canadian and northern US hard spring wheat varieties differing in kernel hardness. Canadian Journal of Plant Science 88: 873-883.

H. Lan, R. Hoover, L. Jayakody, L. Qiu, E. Donner, M. Båga, E.K. Asare, P. Hucl, and R.N. Chibbar. 2008. Impact of annealing on the molecular structure and physicochemical properties of normal, waxy and high amylose bread wheat starches. Food Chemistry 111: 663-675.

B. Verma, P. Hucl and R. N. Chibbar. 2008. Phenolic Content and Antioxidant Properties of Bran in 51 Wheat Cultivars. Cereal Chem. 85: 544-549.

R. Singh, M. A. Matus-Cádiz, M. Båga, P. Hucl and R. N. Chibbar. 2008. Comparison of Different Methods for Phenotyping Preharvest Sprouting in White-Grained Wheat. Cereal Chem. 85: 238-242.

M. A. Matus-Cádiz, T. E. Daskalchuk, B. Verma, D. Puttick, R. N. Chibbar, G. R. Gray, C. E. Perron, R.T. Tyler and P. Hucl. Phenolic Compounds Contribute to Dark Bran Pigmentation in Hard White Wheat. 2008. J. Agric. Food Chem., 56: 1644–1653.

Posters, etc.

Rajender Singh, Pierre Hucl, Monica Båga, Ravindra N Chibbar, 2008. Validation and Marker Assisted Backcrossing of a Major QTL Associated with Pre-harvest Sprouting Resistance in Bread Wheat. PAG, Poster, San Diego CA, January 2008.

Brij Verma, Pierre J. Hucl and Ravindra N. Chibbar, 2008. Phenolic Content and Antioxidant Properties in the Bran of 51 Wheat Varieties. 13th ICC Cereal and Bread Congress, Poster, Madrid Spain, June 15-18.

Brij Verma, Pierre J. Hucl and Ravindra N. Chibbar, 2008. Variations in Total Extractable and Individual Phenolic Acids and Antioxidant Properties of Wheat Bran Extracts Based on Basic and Acidic Hydrolysis. 13th ICC Cereal and Bread Congress, Poster, Madrid, Spain, June 15-18.

Commercializable Property

CDC Imagine CWRS CLEARFIELD wheat. Launched in 2005. First CL spring wheat released in North America. Second globally.

CDC Go CWRS wheat to be marketed by Individual Pedigreed Seed Growers (Public Release) (2007 launch)

CDC Osler CWRS wheat to be marketed by Individual Pedigreed Seed Growers (Public Release) (2007 launch)

CDC Walrus CWES wheat (Public Release), (2008 launch)

CDC Alsask CWRS wheat to be marketed by Viterra (2009 launch)

CDC Abound CLEARFIELD wheat (2009 launch by Viterra and BASF). Second CL spring wheat released in North America.

Winfield hrs spring wheat marketed by Hyland Seeds in Ontario (2006 launch)

Hobson hrs spring wheat marketed by Hyland Seeds in Ontario (2008 launch)

CDC Zorba Spring Spelt wheat. (Public Release) (2010 launch?)

CDC Togo canaryseed marketed by Canterra Seeds (2006 launch)

CDC Bastia canaryseed (Public Release), (2010 launch?)

Durum and High Yielding Spring Wheat Breeding and Genetics

Principal Investigator: C. Pozniak

Overall Program Objectives

A. Durum Wheat: To develop conventional strength durum wheat varieties 5% higher yielding than AC Avonlea, with similar maturity and protein content, but stronger gluten. A second objective is to develop durum wheat varieties with extra-strong gluten properties with higher protein concentration than Commander. Improved resistance to the orange blossom wheat midge, wheat stem sawfly, leaf spotting diseases (especially tan spot) and improved resistance to Fusarium head blight are major breeding objectives for both the conventional and extra-strong gluten types. All cultivars developed will possess reduced cadmium content (<100 pbb) and high yellow pigment concentration (similar to AC Navigator).

B. High-yielding CPS Wheat: The CDC High yielding wheat focuses on CPS-red (90%) and CPS-white types (10%). The major objectives of the high yielding wheat program are to develop varieties with high grain potential, appropriate maturity, acceptable end-use quality, and improved disease and pest resistance. Efforts to develop high yielding CPS-red wheats to service the ethanol and feed industry are ongoing.

Activities and Results

A. Conventional and Extra-Strong Gluten Durum Wheat

Crossing, F_1, F_2, and F_3 Generations

A total of 70 new populations were generated in 2008 during the course of two crossing cycles (winter, summer). Thity-five new crosses targeting Clearfield® durum were also made. Selection for low cadmium concentration was performed in the F_1 generation of the three way crosses ensuring that all progeny will be homozygous for the low cadmium trait. As in 2007, crossing to target midge resistance (*Sm1*) and sawfly resistance was a top priority. For the remaining crosses, the F1 generation was increased in New Zealand. Approximately 70 F2 populations were evaluated and either harvested in bulk (without selection), or in a space nursery with selection. For those populations that were space planted single plant selections were made for either the semi-dwarf trait, and/or the solid stem trait (significantly reduces damage caused by the wheat stem sawfly). Ten F2 populations were selected for single seed decent in which approx. 400 random heads were selected at random and advanced to the F4 generation in the greenhouse over the winter months. Approximately 80 F3 populations were increased in New Zealand to generate the required seed for 2009 testing.

F4, F5 and F6 generations

Approximately 80 F4 populations were evaluated in space plant nurseries. All populations are low cadmium types (100% progeny are low cadmium). Ten populations segregating for midge resistance were evaluated and selected plants are currently being evaluated using molecular markers to identify putative midge resistant plants (i.e. those carrying *Sm1*). Those populations known to be segregating for major rust resistance genes were space planted in artificially inoculated leaf and stem rust nurseries. Approximately 21,000 single plants were selected based on rust resistance, plant height and plant stature. One head was selected from each plant, threshed and evaluated visually for kernel quality (vitreous kernels, red smudge, black point) and seed plumpness and size.

Approximately 25,000 F5 lines were evaluated in hill plots and were selected for plant height, maturity and resistance to lodging. Approx. 10,000 surviving hills were bulk harvested and selected for quality analysis. 500 lines derived from crosses to improve FHB resistance were evaluated as row plots at the Carman, MB FHB nursery. Lines with improved resistance will be evaluated in unreplicated yield trials in 2009. Approx. 3100 F6 Clearfield® lines were evaluated in unreplicated yield tests.

Early Generation Yield Testing

Approximately 4200 lines were evaluated in unreplicated yield trials at Saskatoon and/or Swift Current. Lines were evaluated for days to maturity, plant height, and resistance to lodging. Each line was also evaluated simultaneously for rust resistance in artificially inoculated nurseries. Significant leaf disease allowed for discard of those lines with poor resistance to the leaf spotting complex (tan spot and Septoria). Based on field and disease resistance evaluation, approximately 2000 lines were retained for quality testing which included physical quality (test weight; kernel weight) protein concentration, yellow pigment concentration, resistance to sprouting (as determined using the falling number test) and gluten strength (as determined using a gluten index). Approx. 500 lines will be advanced to replicated yield trials in 2009. Quality evaluation for lines carrying *Sm1* revealed that many of these lines had poor protein concentration and further research is required to determine if linkage drag (*Sm1* was introgressed from hexaploid wheat) is the problem, or if the *Sm1* gene itself is causing the problem (pleiotropy). Approx. 90 lines expressing the solid stem trait have been advanced to replicated yield testing in 2009.

Preliminary Yield Tests

Approximately 4900 lines were evaluated for agronomic performance in replicated yield trials at Saskatoon, Goodale, Swift Current, and either Lethbridge or Avonlea. Each line was also evaluated for resistance to the rusts (Saskatoon), FHB resistance (Carman, MB), and leaf spot resistance. Leaf spots were extensive in 2008at Goodaleallowing effective selection for this disease complex. Extensive quality evaluation was also conducted including pilot scale milling and detailed evaluations of semolina colour, ash content, and rheological properties.

Advanced Yield Tests

All advanced yield testing of durum wheat lines is done in a co-operative manner with the Agriculture and Agri-Food Canada durum wheat breeding program at Swift Current. The CDC durum program continues to co-ordinate the advanced quality testing of the Western Durum A Test. A total of 41 lines were evaluated in replicated trials at a minimum of five locations in Western Canada. Data collected included agronomic performance, disease resistance (leaf and stem rust; loose smut; Fusarium head blight in Carman and Portage, MB and Ottawa, ON; leaf spots at Brandon, Goodale, Regina, and Swift Current); and extensive end-use quality evaluation including pilot scale semolina milling and rheological tests (Alveograph measurements). Grain cadmium concentration was measured on all lines using mass spectrophotometry following digestion of samples with nitric acid/perchloric acid. Based on agronomic performance, disease resistance, and end-use quality, four lines from these trials will be advanced to the Durum co-operative tests in 2009.

Co-op Testing

In 2008, six first year lines were evaluated in the Durum registration co-operative tests. DT557, DT561, and DT562 have advanced to second year of testing. All of these lines are conventional strength types and show improved yield (5-12%) over Strongfield, with similar maturity. Leaf spot resistance in these three lines is also similar to Strongfield, our most tolerant check. Short breeder rows of DT557, DT561, and DT562 were evaluated for off types and surviving rows will be planted in 2009 as medium breeder rows.

Durum Wheat Germplasm Evaluations

In 2008, approx. 100 advanced breeding lines from CIMMYT and ICARDA were evaluated in unreplicated/replicated yield trials. The majority of these lines were found to be significantly lower yielding than Strongfield (high yielding durum wheat check). Since the durum program at AAFC-SPARC evaluates similar lines, we are combining our databases to improve estimates of phenotypic worth. One or two of the best lines will be used in our 2009 crossing program. These lines have resistance to a new leaf rust race that has emerged as a problem in Mexico and California and that is virulent against many of our Canadian cultivars.

UG99 Evaluation

Advanced lines from our durum wheat breeding program were evaluated in Kenya for resistance to UG99 and for seedling resistance by Dr. Tom Fetch, AAFC-Cereal Research Centre. Infection at Kenya was high in susceptible checks, and all of our advanced breeding lines were rated as moderately resistant or resistant. Approx. 96 durum cultivars and breeding lines used as parents in our breeding program (past and present) were also evaluated. CDC Verona and Strongfield were highly susceptible to UG99, but Commander displayed good seedling and adult plant resistance. AC Napoleon continues to show good resistance to UG99 in both the field and seedling tests. All of our 2009 advanced breeding lines will again be evaluated for UG99 resistance in Kenya on a per-for-service basis.

B. High Yielding Wheat

Crossing, F_1, F_2, and F_3 Generations

A total of 40 crosses were made in winter and summer crossing blocks. All F_1 populations were increased in New Zealand. A total of 40 F2 populations were evaluated in bulk plots in an artificially inoculated leaf and stem rust nursery. Following harvest, seeds were screened for plumpness on a gravity table. We have found that this method works well to select those seeds produced by the disease free plants (since severely diseased plants tend to produce shrivelled seeds). The resulting F2 seed was sent to New Zealand for generation advancement. New for 2008, several crosses targeting the General Purpose Wheat class were developed, with the objective of pyramiding stable rust resistance genes (*Lr21*, *Lr22a*, and *Lr34*) with FHB (*Fhb1*, *Fhb2*, *Fhb3)* and seed dormancy into soft white wheat. A backcrossing program has been initiated for this project and F1 plants from 10 complex crosses were screened with molecular markers linked to these genes to identify only those plants that carry the desirable gene complex. Five additional backcrosses were also made to incorporate the low phytate trait from a US soft white wheat into a Canadian soft white wheat background. Low phytate plants have been identified and are currently being crossed to those plants carrying the disease resistance complex (listed above). This is the only conscious effort to breed General Purpose Wheats, with most efforts being placed on the development of CPS red wheats targeted for the milling market.

F4, F5 and F6 generations

Forty F4 populations were evaluated in a space plant nursery artificially inoculated with leaf and stem rust. Approximately 350 single plants with desirable plant height and acceptable levels of leaf and stem rust resistance were selected from each of the populations. A total of 21,000 F5 lines were evaluated as hill plots in an irrigated leaf and stem rust nursery and were selected for resistance to the rusts, plant height, maturity, and plant stature. One head from each surviving hill was selected and evaluated visually for seed size, plumpness and for KVD. In 2008, approximately 6100 lines were evaluated in F6 head rows. Selection was primarily based on resistance to the wheat rusts, plant height, maturity, and resistance to lodging. Molecular marker assisted selection for wheat midge resistance (Sm1) and Fusarium Head Blight resistance (*Fhb1, Fhb2, Fhb3* gene) is currently being performed on surviving lines known to be segregating for those traits. Extensive screening of F5 selections for two molecular markers linked to *Lr21* and *Lr34* was also completed. The combination of these two resistance genes will provide effective and stable resistance to leaf rust. Approx. 3100 lines (note this is an estimate at this time as quality evaluation is still being conducted) will be advanced to 2009 testing.

Early Generation Yield Tests

Approx 1800 lines were evaluated in unreplicated yield trials at Saskatoon. Approximately 95% of the lines were red-seeded CPS types based on the NaOH test for seed colour. Lines were simultaneously evaluated for common bunt resistance (Saskatoon), leaf/stem rust resistance (Saskatoon), and FHB resistance (only lines known to contain putative resistance genes) at Carman, MB. Only those lines with appropriate maturity, lodging resistance and an adequate disease resistance package were harvested. Once harvested, those lines with yield potential equivalent to AC Vista were evaluated for physical grain quality (test weight and kernel weight), grain protein concentration, sprouting resistance (as assessed using the falling number test), and gluten strength (SDS sedimentation test). Several lines with midge resistance were identified based on visual inspection of seed samples. Given the high midge pressure observed in 2008, selection was very effective for that trait in those populations segregating for *Sm1*

Preliminary Yield Tests

Approx. 240 lines were evaluated in replicated yield trials at Saskatoon, Watrous, Lake Lenore and Wakaw. As with the early generation yield tests, all lines were simultaneous evaluated for disease resistance (loose smut, common bunt, leaf/stem rusts, common bunt and FHB). Approx. 20% showed acceptable levels of resistance. Approximately 60% of the lines evaluated had FHB scores significantly lower (more resistant) than AC Barrie combined with good resistance to the rusts. Surviving lines were extensively evaluated for physical grain quality (test weight, kernel weight, kernel hardness), and end-use quality, including pilot scale milling, flour rheological properties and colour and bake tests.

Advanced Yield Tests

A total of 13 lines were evaluated in co-operative yield tests with Agriculture and Agri-Food Canada. All lines were tested at six sites in Western Canada and were extensively evaluated for disease resistance and end-use quality. These lines were also evaluated for resistance to UG99, and all but four were rated as moderately resistant. The four rated as susceptible will still be advanced as they had the lowest FHB scores (more resistant) of the 13 lines. Two lines have been advanced to the 2009 General Purpose Wheat Co-operative test.

Co-op Tests

The CDC program is responsible for the co-ordination of the General Purpose (GP) Spring Wheat Co-operative test and is responsible for all seed increases and field trial and disease nurseryco-ordination. Five CPS-white seeded lines designated as GP003 (third year), GP040, GP041, GP043, and GP044 (all first year lines) were evaluated in the 2008 General Purpose Wheat Co-op. GP003 was supported for registration at PGDC-WRT annual meetings held in Banff in February 2009. GP003 yielded only 5% lower than AC Andrew, but matured 3-5 days earlier. GP003 has consistently shown protein concentration approx 1.5-2% lower than the bread wheat checks, and maybe useful as for fuel/feed. This line is susceptible to FHB, so production would be restricted to the western portion of the prairie wheat growing area. GP040 also showed good yield potential and early maturity and has been advanced to a second year of testing in the 2009 General Purpose Co-operative Test.

HY532, a CPS-red seeded wheat was evaluated in the 2008 High Yield Red Wheat Co-operative test, and was the the highest yielding experimental line in that test. However, this line had lower protein concentration and was thus advanced to the 2009 General Purpose Wheat Co-operative Test. If the yield potential holds, this line could be supported for registration in 2010.

Methodology

Early generation (F_1-F_6) testing methodology was presented above for both the durum and CPS programs. For yield tests, standard 5-row yield plots with rows 3.6 m long and 20 cm apart were used at most locations. Pre-breeder seed development for all lines in the 1st year of Co-op testing was initiated by selecting a minimum of 250 single spikes from a roughed increase plot. All quality testing in advanced yield testing is conducted using American Association of Cereal Chemists (AACC)-approved methods. In earlier generations (F6 rows and Early generation yield testing), quality parameters (protein concentration, yellow pigment concentration, grain hardness) are predicted using NIRS technology.

Expected Outcomes

Expected outcomes of the CDC durum/high yielding wheat breeding program include increased economic returns to producers and the province by providing:

- lowering costs of production by improving disease resistance;
- Incorporation of novel sources of Fusarium resistance into durum wheat;
- improved food quality (low grain cadmium concentration);
- access to higher return durum markets (extra-strong durum; specialty durums);

- higher yielding durum, CPS-red (milling) and General Purpose wheat (feed/fuel) cultivars;
- Integration of genomics and molecular assisted breeding to improve breeding efficiency and to better understand the physiological processes associated with key crop traits;
- Training of highly qualified personnel at the technical and professional levels;
- Assist in technology transfer to the Saskatchewan and Canadian Wheat Industry.

Durum Wheat/High Yielding Wheat Outputs

Outputs for 2008-09 include the following:

- Registration of CDC Verona by the CFIA was obtained. CDC Verona combines good yield, low cadmium concentration, and excellent end-use quality. CDC Verona also has improved FHB tolerance over current commercial cultivars. Certified seed production of CDC Verona commenced in 2008-09 and a plant breeders rights application was submitted. CDC Verona is marketed by Paterson Grain LTD. GP003, a GP wheat, was supported for registration in February, 2009.
- Dr. Pozniak supervises the marker assisted selection efforts for all of the wheat breeding programs at the CDC and in 2008-09, approx. 38,000 data points were collected for one or more of the following traits: Leaf rust resistance (*Lr21, Lr34*), seed dormancy, FHB resistance (*Fhb1, Fhb2, Fhb3*), lypoxygenase activity (*Lpx-B1.1*), midge resistance (*Sm1*) and for elevated yellow pigment (*Psy1-B1; Psy1-A1, gwm193*) in durum wheat. Funding for additional equipment for single nucleotide polymorphism (SNP) markers is being sought (array-based screening of several hundred SNPs from a single genotype in one run). This technology, coupled with high-throughput 454 sequencing, has advanced in the last five years and has become an economical alternative to microsatellite markers in wheat.
- Conducted Durum SAC Trials at Saskatoon;
- Co-ordinated the General Purpose Wheat co-operative test, PGDC-WRT;
- Invited talk at the International durum wheat Symposium, Bologna, Italy;
- Participated in an European durum wheat marketing mission with the Canadian Wheat Board;
- Scientific manuscripts published in 2008-2009 (7)

Y Suprayogi, CJ Pozniak, FR Clarke JM Clarke, and RE Knox, and AK Singh. 2009. Identification and validation of quantitative trait loci for grain protein concentration in adapted Canadian durum wheat populations. Theoretical an Applied Genetics *accepted.*

A. Singh, S. Reimer, CJ Pozniak, FR Clarke JM Clarke, and RE Knox, and AK Singh. 2009. Allelic variation at *Psy1-A1* and association with yellow pigment in durum wheat grain. Theoretical an Applied Genetics, *in press*

C Campoli, M Matus-Cádiz, CJ Pozniak, L Cattivelli, and DB Fowler. 2009. Cloning, characterization and low-temperature expression analyses of the Cbf gene family of rye *(Secale cereale L.)* Molecular Genetics and Genomics, *accepted.*

FR Clarke, JM Clarke, CJ Pozniak, and TM McCaig. 2009. Protein Concentration Inheritance and Selection in Durum Wheat. Canadian Journal of Plant Science, *accepted.*

C. J. Pozniak, S. Fox and D.Knott. 2009. CDC Verona Durum Wheat. Canadian Journal of Plant Science, in press.

S. Reimer, C. Pozniak, F. Clarke, J. Clarke, D. Somers, and A. Singh. 2008. Association mapping of yellow pigment in a diverse collection of durum wheat accessions. Genome, 51: 1017-1025.

M. Matus-Cadiz, C.J. Pozniak, and P.J. Hucl. 2008. Puroindoline allele diversity in Canadian and northern US hard spring wheat varieties differing in kernel hardness. Canadian Journal of Plant Science.

Mansucripts currently under Peer Review (4)

A Singh, C. J. Pozniak, F. Clarke, R. Knox, J. Clarke, and A.K. Singh. 2009. QTL Mapping of Lutein and Zeaxanthin and Associations with Yellow Pigment in Durum wheat (Triticum turgidum var. durum). Theoretical and Applied Genetics: under peer review.

R. Knox, C. J. Pozniak, J. Clarke, and F. Clarke. 2009. Chromosomal Location of a low grain cadmium concentration locus in wheat. Genome, under peer review.

J. Clarke, F. Clarke, C.J. Pozniak, and R. Knox. 2009. Inheritance of test weight and kernel weight in eight durum wheat crosses. Canadian Journal of Plant Science, under peer review.

P. Hucl, F.A. Holm, K. Kirkland1, E. Johnson and C.J. Pozniak. 2009. Competitive ability of western Canadian spring wheat cultivars in a model weed system. Canadian Journal of Plant Science, under peer review.

- Posters and Presentations

C.J. Pozniak, 2008. Genetics of Endosperm Colour in Durum Wheat. **Invited Talk:** International Durum Wheat Symposium, June 28-July 3, 2008, Bologna, Italy.

C. Muñoz-Florez, C. Campoli, M. Matus-Cádiz, C.J. Pozniak and D.B. Fowler. Effect of Photoperiod on the Regulation of Rye (Secale cereale) Scvrn-1 vernalization gene and its repressors ScVrn-2 and ScVrt-2. Proceeding of the XVII Plant and Animal Genome Conference, January 10-14th, 2009, San Diego, USA.

C.J. Pozniak, S. Reimer, D.J. Somers, FR Clarke, JM Clarke, R.E. Knox, A.K. Singh, and T. Fetch. 2008. Association mapping of UG99 Resistance in a Diverse Durum Wheat Population. Proceedings of the 11th International Wheat Genetics Symposium. August 24-29, 2008. Brisbane, Australia

F.R. Clarke, JM Clarke, C.J. Pozniak, DJ Somers, JE Dexter, RE Knox, S. Reimer, T. McCaig, and AK Singh. 2008. Association Mapping of Semolina Yield in a Diverse Durum Wheat Population. Proceedings of the 11th International Wheat Genetics Symposium. August 24-29, 2008. Brisbane, Australia

S Houshmand, RE Knox, FR Clarke, JM Clarke, and CJ Pozniak. 2008. Quantitative Trait Loci Associated with Kernel Weight and Test Weight in Durum Wheat. Proceedings of the 11th International Wheat Genetics Symposium. August 24-29, 2008. Brisbane, Australia

C. Pozniak, K. Wiebe, N. Harris and G. Taylor. Identification and Mapping of Candidate Genes Regulating Cadmium Accumulation in Durum Wheat (**Triticum turgidum** L var **durum**). Proceedings of the International Durum Wheat Symposium, June 28-July 3, 2008, Bologna, Italy.

A. Singh, C. J. Pozniak, F. R. Clarke, N. P. Ames, R.E. Knox, J.M. Clarke, A.K. Singh, 2008. QTL Mapping of Lutein and Zeaxanthin in Durum wheat (**Triticum turgidum** var. **durum**). Proceedings of the International Durum Wheat Symposium, June 28-July 3, 2008, Bologna, Italy.

Y. Suprayogi, C.J. Pozniak, F.R. Clarke, J.M. Clarke, and R.E. Knox, and A.K. Singh, 2008. Quantitative Trait Loci for Elevated Grain Protein Concentration in a Canadian Durum Wheat Population. Proceedings of the International Durum Wheat Symposium, June 28-July 3, 2008, Bologna, Italy.

- Teaching/Graduate Student Supervision:
    - Two graduate Students Successfully defended their theses
        - Sherisse Reimer (M.Sc).
        - Bandla Rao (M.Sc).
    - Current Students:
        - Addy Ramachandran (M.Sc)
        - Krystalee Wiebe (M.Sc)
        - Yogi Suprayogi (Ph.D.)
- Graduate Student Supervisory committee for 5 M.Sc/3 Ph.D students
- Public Service and Outreach Activities:
    - Canadian Seed Trade Association Representative, International Working Group on Molecular Markers for Variety Development, International Seed Federation, 2008
    - Member, International Durum Wheat Symposium International Scientific Advisory Committee, 2008
    - Member, International Wheat Quality Conference Planning Committee, 2008
    - Invited Meeting, Saskatchewan Agri-Arm Sites Planning Meeting, April 17th, 2008
    - Secan Molecular lab tour, Jan 10, 2008
    - Lab Tour, Mongolia Breeding Group, February 20th, 2008
    - Lab and field Tour, KWS-Lochow/Technische Universitat Munchen, May 14-15th, 2008
    - Invited Meetings, Canadian Wheat Board Durum Wheat Quality Investigative Mission, June 30st-July 14th, 2008
    - Lab and Field Tour, Durum Wheat Breeding Group, Universidad de Chile, Ministerio de Agricultura, INIA June 3rd-4th, 2008.
    - BASF Breeding Update and Field Tour June 17th, 2008
    - 8 Producer calls on production/management of durum and CPS wheat.
    - Field Tour, WGRF Technical Advisory Committee, July 16th, 2008
    - Invited Talk: CWB Durum Wheat Meeting, Elrose, Saskatchewan January 28th 09
    - Invited Talk: Richardson International: New Durum Wheat Varieties, Saskatoon, Saskatchewan, March 5th, 08

Durum and High Yielding Wheat Research Projects

Project: Use of Genomics Tools for Crop Improvement in Temperate Climates
Funding source: Genome Canada
Term: 2006-2010.
Principal Investigators: D.B. Fowler, R. Chibbar, C. Pozniak
Approved budget: $8,145,734

Summary

For this project, we are assessing the genetic differences between wheat, barley and in rye, to better understand what makes rye more cold tolerant than wheat and barley. In wheat, *Cbf* genes are considered master switches regulating response to cold and are candidate genes for low-temperature (LT) tolerance QTL localized at Fr-A2. However, most functional studies of *Cbfs* have focused on characterizing expression after LT exposure and have not quantified differences associated with the rate of response. In the *Triticeae*, rye *(Secale cereale)* is one of the most LT tolerant species, and is an excellent model to study and compare *Cbf* LT-induction and rate of response. Here we report on the isolation of rye *Cbf* genes and compare *their* expression levels in spring- and winter- habit rye cultivars varying in LT response, and two winter-habit wheat and barley cultivars. Eleven *Cbf*s were isolated spanning all four major phylogenetic groups. Nine *Cbf*s mapped to 5RL and one to chromosome 2R. *Cbf* expression levels were variable with stronger expression in winter- vs. spring-habit cultivarsbut no clear association between expression of any one *Cbf* and cultivar differences in LT were detected. *Cbfs* expressed at warmer acclimation temperatures were repressed after 48-h, at the end of an 8-h dark period, and may reflect light-regulated diurnal response. Our work indicates that *Cbf* expression is regulated by complex gene by time by induction-temperature interactions and sample-timing, induction-temperature, and light-related factors must be considered in future studies involving functional characterization and mapping of LT induced genes in cereals.

In *T. monococcum,* a complex system regulating the transition from vegetative to reproductive growth, and thus cold tolerance, has been reported. However, our current understanding of the expression profiles of Scvrn-1 and its repressors, if any, in winter rye) cvs. 'Puma' and 'Sangaste' is non-existent. The objective of this study was to compare the RNA transcript expression profile of Sc*Vrn*- 1, Sc*Vrn*-2, and Sc*Vrt*-2 in rye cvs. Puma (winter type; Scvrn-1), Sangaste (winter type; Scvrn-1), and Gazelle (spring type; ScVrn-1) grown under long day (LD, 16h) and short day (SD, 8h) photoperiods. Winter wheat cultivar Norstar was included as a control. Under LD conditions, Sc*Vrn*-2 was down-regulated after 2 days of vernalization but transcripts in Puma and Sangaste begin to accumulate only after 14 days of cold-acclimation. In contrast, ScVrn-2 expression was not detected under SD conditions at any of the sampling times, but Sc*vrn*-1 transcripts began to accumulate after 35 or 42 days of cold-acclimation. A similar pattern was observed in Norstar. Our results suggest that *Scvrn*-2 expression is influenced by photoperiod with the result that SD delays the transition from vegetative to reproductive growth. In addition, underlong days, *Scvrn-2* in rye appears to be regulated by a light induced diurnal rhythm. These results suggest that *vrn-2* may not be a suppressor of *vrn-1* in cereals and may have little to do with regulation of cold tolerance as previously suggested.

Project: Integrating Functional Genomics and Genetic Mapping to Clone Genes Responsible for Low Grain Cadmium Concentration in Durum Wheat

Funding Source: NSERC Strategic Grant Program
Co-Investigators: C. Pozniak/G. Taylor
Duration: 2006-2009
Amount: $388,534

Summary: Grain cadmium (Cd) concentrations in durum wheat (Triticum turgidum L. var durum) can exceed proposed international trade limits of 100 ppb, particularly when grown in soils high in Cd. Genetic differences in Cd uptake are known and genotypic differences are most closely associated with differences in Cd root-to-shoot translocation. A single QTL for Cd uptake has previously been reported on 5B, but the genetic factor(s) conferring the low Cd phenotype are currently not known. We are using a combination of forward and reverse genetic approaches to identify candidate genes involved in regulating Cd accumulation in grain. To date, we have compared root gene expression profiles in two pairs of durum wheat near-isogenic lines (NILs), high and low for Cd accumulation. Less than 40 genes were differentially expressed between the high and low Cd-accumulating NILs. These include genes encoding for developmentally regulated glycoproteins, stress-inducible proteins, and ABC transporter proteins. We are currently bin mapping these genes to identify those candidates that reside on 5B. Genetic mapping coupled with chromosome localization in aneuploid stocks suggests that the gene(s) associated with variation in Cd partitioning reside in wheat bin 5BL9. We are continuing to map several available expressed sequence tags (ESTs) previously localized to this bin (http://wheat.pw.usda.gov/wEST/ binmaps) and haved identified several possible candidate genes for further analysis and mapping. One of these is predicted to code for a ABC transporter near the *vrn-B1* locus in durum. This gene is a logical candidate as ABC transporters have been associated with intracellular Cd sequestration and Cd tolerance in *Arabidopsis*. We have confirmed that this gene resides on chromosome 5B within the *Cdu1* locus and we are currently mapping this gene in several mapping populations to determine its role in Cd accumulation in durum wheat grain.

Project: Genetics and Genomics of Pasta Colour in Durum Wheat

Funding Agency: Western Grains Research Foundation/NSERC
Principal Investigators: C. Pozniak
Term: March 2004-March 2010
Approved Budget: $121,000

Summary: The yellow colour of durum wheat semolina is due in part to the presence of carotenoid yellow pigments found in the endosperm and is an important end-use quality trait. We hypothesized that variation in the genes coding for phytoene synthase (Psy), a critical enzyme in carotenoid biosynthesis, may partially explain the phenotypic variation in endosperm colour observed among durum cultivars We have sequenced a bacterial artificial chromosome (BAC) containing Psy1-B1, and have identified flanking genes for use in fine mapping experiments. We have screened approx 2500 F2 plants (derived from crossing of lines near isogenic at *Psy-B1*) for genetic recombinants around *Psy-B1* and have identified several F2:3 families for detailed phenotyping. In addition, we are characterizing the expression of this gene throughout the grain fill period, and have found that pigment differential expression between high and low pigment lines occurs 21 days post-anthesis. This work is necessary to confirm that the *Psy1* genes identified are the casual genes influencing yellow pigment expression in durum wheat.

Studies are also being conducted to understand the genetics of expression of chemical components that make up yellow pigment: lutein and zeaxanthin, the major components of grain pigments. High-performance liquid chromatography (HPLC) was used to quantify lutein and zeaxanthin concentrations and major lutein QTLs located on chromosomes 2A, 4B, 6B, and 7B. Additional QTL for zeaxanthin were identified on chromosomes 2B and 5B. We are currently using wheat-rice synteny to sequence and determine the association with all known carotenoid biosynthetic genes with variation in lutein and zeaxanthin in durum wheat. We have sequenced a lycopene-beta cyclase gene, and current results suggest that this gene is a strong candidate for the lutein and zeaxanthin 6B QTL. We have developed a TILLING population of CDC Verona (a high pigment variety) and have identified mutants for lycopene-beta cyclase. These mutants will now be used to understand the expression and regulation of this gene as it relates to yellow pigment in durum wheat grain.

Project: A Novel Approach to Identifying Quantitative Trait Loci in Cereal Crops.
Funding Agency: NSERC Discovery ($135,000 2005-2010)
Principle Investigators: C. Pozniak

Summary: The development of new approaches to facilitate QTL identification, and the isolation and functional characterization of genes underlying quantitative traits is an important component of our overall research program. For this proposal, we are using available germplasm, and the molecular and end-use quality data we have collected over years of extensive field evaluation as a tool to assess the potential of association mapping (AM) in wheat. AM not only allows for a greater assessment of allelic variation, but allows mapping in breeding materials and germplasm pools. The latter point is important, as my primary responsibility at the Crop Development Centre is durum wheat breeding. We have performed genome-wide AM for several traits using a series of ninety-three genetically diverse durum cultivars. Each accession was scored with 245 microsatellite markers and assessed for yellow pigment concentration, UG99 resistance, and semolina milling yield. UG99 resistance was assessed at an endemic nursery in Kenya (2007) and in greenhouse studies (2008). Nearly half of the durum wheat accessions evaluated were scored as moderate to highly resistant. The remaining lines were intermediate (n=25), moderately susceptible (n=21) or susceptible (n=10). Marker associations for UG99 were identified on several chromosomes, suggesting multiple resistance genes exist in durum. On chromosme 7A, *Xgwm276* was associated with response to UG99. *Xgwm276* is linked to *Sr22*, which is known to be effective against UG99. Marker associations were also identified on the distal end of 5A; and *Xwmc537* and *Cdu1* on 5B were also significant. Although the association on 5B is in a region were *Sr* genes have yet to be identified, this region has been associated with stem rust resistance in hexaploid wheat. An association with LOX gene *Lpx-B1.1* was detected and further validation is a priority as elevated LOX activity may confer resistance, but would result in excessive colour loss in pasta products. Field screening will be repeated in 2009, and those genomic regions consistently identified as being associated with UG99 resistance will be the target of detailed validation experiments for use in marker assisted selection. In collaboration with Dr. K. Ammar (CIMMYT), we are current mapping a durum wheat population to verify some of the markers identified.

Marker associations for semolina yield in this population was also conducted and identified regions on chromosomes 2A, 2B, 4A, 5B, 6A and 7A. More tentative indications were observed on 1A, 3A, 3B, 5B, and 7B. Test weight and kernel weight are known to be positively associated with semolina yield, so we checked to see if any of the observed semolina QTL coincided with test weight or kernel weight QTL. The 6A region showed a weak semolina yield QTL, and was flanked with a moderate test weight QTL. The 2A region, flanked by *wmc522-gwm95, was also* coincided with a strong kernel weight QTL. The 7A region *wmc809* coincided with a moderate kernel weight and moderate to strong test weight QTL. In the latter case, the QTL associations for kernel and test weight were not as strong (ie. less significant) as the observed semolina yield QTL association, suggesting the possibility of additive effects of this locus on semolina yield. After discounting loci that are possibly indirectly linked to semolina yield through test weight or kernel weight, there were still strong, consistent associations with semolina yield on chromosomes 2B, 4A, 5B and 7A, and indications on 1A, 3A and 3B. We are now validating the QTL identified in this AM population in several genetic mapping populations.

Project: QTL Mapping and Physiological Study of High Grain Protein Concentration in Canadian Durum Wheat.
Y. Suprayogi and C.J. Pozniak
Funding Agency: NSERC, Discovery (as above)

Summary: Grain protein concentration (GPC) is one of the most important factors influencing pasta-making quality. Durum wheat (*Triticum turgidum* L. var *durum*) cultivars with high GPC produce pasta with increased tolerance to overcooking and greater cooked firmness. However, the large environmental effect on expression of GPC and the negative correlation with grain yield have slowed genetic improvement of this important trait. Understanding the genetics and identification of molecular markers associated with high GPC would aid durum wheat breeders in trait selection at earlier generations. The objectives of this study were to identify and validate molecular markers associated with quantitative trait loci (QTL) for elevated GPC in durum wheat. A genetic map was constructed using SSR and DArT® markers in an F_1-derived doubled haploid (DH) population derived from the cross DT695 x Strongfield. The GPC data were collected from replicated trials grown in six Canadian environments from 2002-2005. QTL associated with variation for GPC were identified on the group 1, 2, and 7 chromosomes and on 5B and 6B, but only *QGpc.usw-B3* on 2B and *QGpc.usw-A3* on 7A were expressed consistently in four and six environments, respectively. Positive alleles for GPC at these loci were contributed by the high-GPC parent Strongfield. The *QGpc.usw-A3* QTL was validated in a second DH population, and depending on environment, selection for the Strongfield allele at *barc108* resulted in +0.4% to +1.0% increase in GPC, with little effect on yield in most environments. Given the consistent expression pattern in multiple populations and environments, *barc108* could be useful for marker-assisted selection for high GPC.

Project: Enhancing the Bread-baking Quality of Durum Wheat Cultivars.
N. Bandla, C. Perron, P. Hucl, and C.J. Pozniak
Funding Agency: NSERC, Discovery (as above)

Durum is used predominantly for semolina and pasta products, but there is increasing interest in using durum for bread-making to provide alternative markets during periods of overproduction. The goal of this study was to characterize the bread-making quality of durum wheat cultivars and emmer derived breeding lines derived from crosses of durum wheat with an Emmer land race '97Emmer19' from Iran. Emmer-derived breeding lines were evaluated along with three high quality bread wheat cultivars and seven durum wheat cultivars across three environments in replicated yield trials. Four 1AS.1AL-1DL translocation lines which carry the *Glu-D1d* allele from chromosome 1D of bread wheat were also evaluated. In general, durum wheat cultivars with elevated gluten strength and/or increased dough extensibility were noted to have higher loaf volume (LV) than those with weaker gluten. The 1AS.1AL-1DL translocation line 'L252' carrying the LMW-1 banding pattern had better dough mixing stability and LV than the translocation lines with the LMW-2 banding pattern. Breeding lines derived from crosses of '97Emmer19' to strong gluten durum cultivars had higher LV than those of the durum checks. '97Emmer19' carried *Glu-A1a** (HMW-GS *1Ax1*) and the progeny carrying that allele generally exhibited higher loaf volumes. These results indicate that there is potential to select for genotypes with improved baking quality in durum breeding programs.

Project: Enhancing Fusarium Head Blight Resistance in Spring and Durum Wheat Using Novel Approaches.
Funding Agency: Saskatchewan Agriculture Development Fund
Principal Investigators: P. Hucl, C. Pozniak, and C. McCartney

In proof of concept experiments, a wild relative of durum wheat, TG3487, was identified as having improved tolerance to FHB compared to commercial durum wheat cultivars., A genetic mapping population consisting of 160 F10 recombinant inbred lines (RIL) from the cross TG3487/2*DT735 was developed. This population is particularly useful for mapping as DT735 also possesses moderate levels of type II resistance and is conferred by different gene(s) than that in TG3487. DT735 is derived from DT696, a source of FHB tolerance that is used extensively by both the CDC and AAFC-SPARC breeding programs, so identification of markers for DT735 derived resistance would have instant application to our durum wheat breeding programs. In innoculated FHB nurseries, the parents TG3487 and DT735 showed intermediate tolerance and Transgressive segregation was evident in the RIL population, with lines in the population displaying resistance similar to FHB37. Approx. 10% of the population showed limited FHB severity, indicative of strong type II resistance in the population. A genetic linkage map was constructed and the 110 markers were joined into 16 linkage groups representing all 14 durum wheat chromosomes. Several regions of the genome were not well represented, and we estimate that an additional 80-100 markers are required to completely saturate the TG3487/2*DT735 genetic map to a density of 1 marker every 2-5 cM. To accomplish this, we have sent DNA of the mapping population for DArT® analysis in Australia. Simple marker analysis was utilized to identify molecular markers associated with FHB tolerance in this population. Seven molecular markers were significantly associated with FHB incidence, and five of these were also significantly associated with a reduction in severity and FHB index . Three of the markers were from chromosome 2B, and two of these (Xbarc167 and Xwmc332) are derived from DT735, and may represent the same QTL. Both parents contributed alleles for reduced FHB incidence, consistent with phenotypic data suggesting segregation for type I resistance in this population. QTL alleles for improved FHB tolerance were identified from both TG3487 and DT735. Several of the QTL identified appear to be similar to those reported in bread wheat. These results are interesting, given the lack of effective resistance provided by many of these QTL when introgressed from bread wheat into cultivated durum wheat. The population will again be evaluated for FHB tolerance in field and greenhouse testing to confirm the encouraging results observed in 2008. The markers identify have already been deployed as a selection tool in our durum wheat breeding program.

Project: Cereal Grains for the Fuel and Feed Industry.
Funding source: Saskatchewan Agriculture Development Fund, Western Grains Research Foundation Endowment Fund, Agriculture and Agri-Food Canada ABIP Program.
Term: 2009-2012.
Principal Investigators: C. Pozniak, P. Hucl, C. McCartney, H. Ranhdawa, R. DePauw
Approved budget: $849,000

The profitability of expanding ethanol production in Saskatchewan is linked to a number of factors including access to a stable supply of quality feedstock. In Western Canada, wheat is the feedstock of choice for ethanol production, and in particular soft white wheat. Wheat-based ethanol production is relatively new, particularly on a large scale with plants exceeding 100 million litres. Research and breeding efforts targeting the needs of the wheat-based ethanol production system are required. In response to the increased demand for wheat as an ethanol feedstock, the CWB and CGC have created the General Purpose Wheat Class (GPWC) to allow registration of non-milling wheat varieties (low protein requirement, de-emphasizing milling/baking end-use qualities) that could be used domestically by the growing number of ethanol plants. In this reporting cycle, we established yield trials and evaluated 192 advanced breeding lines targeted for the GPWC. We also developed several complex crosses aimed incorporating three effective rust resistance genes, midge tolerance (*Sm1* gene), a gene for seed dormancy and three Fusarium head blight tolerance genes (*Fhb1, Fhb2,* and *Fhb3*) into soft white spring wheat and high yielding red seeded wheat. Marker assisted selection for all of these genes was performed and plants carrying the resistance gene complex were identified and selected for further backcrossing/breeding. In addition, two backcross populations to develop low phytate soft white wheat were also completed, and efforts to develop a rapid protocol for phytate assessment using HPLC were validated. Evidence in corn suggests that "waxy" starch properties enhance fermentation potential, and trials were conducted at three locations to evaluate the potential of waxy wheat to improve fermentation potential. Fermentation testing will be completed by April, 2009, and trials will again be evaluated in the field in 2009. Also, a second set of trials using near isogenic lines with all possible combinations of three "waxy" alleles will be conducted. Elevated pentosans in wheat could result in undesirable viscosity problems in ethanol plants. In field studies conducted in 2008, extensive variation for pentosan levels in wheat varieties were observed and suggests that breeding for reduced pentosan levels should be possible in General Purpose spring wheat.

Project: High Amylose Wheat to Improve Human Health
Funding source: Saskatchewan Agriculture Development Fund, Paterson Grain Ltd.
Term: 2009-2012.
Principal Investigators: C. Pozniak, P. Hucl, and J. Dubcovsky
Approved budget: $329,000.

The Glycemic Index (GI) has become the benchmark for classifying carbohydrates and is a measure of how rapidly a food product causes blood sugar to rise, compared with glucose. Foods produced from wheat and durum have a high glycemic index and cause undesirable spikes in blood sugar. Resistant starch (RS) has a low GI as it escapes digestion in the small intestine leading to similar benefits as insoluble fibre. Amylose starch is a form of resistant starch, and efforts to develop high amylose cereals are being pursued intensely. However, attempts to develop wheat and durum products with elevated amylose using available germplasm have not been successful. For this project, we have performed high through-put Targeted Induced Local Lesions in Genomes (TILLING), a genomics technique used to create and identify altered versions of genes known to influence a desired phenotype. Using TILLING, we have already identified plants carrying mutations at two critical genes in starch biosynthesis in two different genetic backgrounds (one is CDC Verona). In 2009, these putative high amylose typed will be fully characterized in field trials to confirm the desired phenotype. Putative high amylose versions of CDC Verona will be increased this summer and in New Zealand in the fall of 2009 to develop sufficient seed for industry assessment of quality.

New Funding Obtained/Applied For in 2008-2009

C.J. Pozniak, P.J. Hucl, R.M. DePauw, H. Randhawa, C. McCartney, Development of Commercial Products from the Wheat Ethanol Process: Germplasm Enhancement. $471,816. Agriculture and Agri-Food Canada. 2008-2012 ($102,000)

C.J. Pozniak, Development of a High Amylose Durum Prototype using TILLING. $123,000. Paterson Grain LTD. 2008-2011. ($38,000).

C. J. Pozniak. Improving human health by elevating levels of resistant starch in wheat. $205,783. Saskatchewan Agriculture Development Fund. 2009-2011. ($70,465).

C.J. Pozniak and J. Dubcovsky. Development of high amylose durum wheat using TILLING. $141,000. Paterson Grain LTD. ($41,000).

A.K. Sing, C.J. Pozniak, I. Wise, B. Marchylo, and F. Clarke. Effect of the midge resistance gene *Sm1* on end-use quality in durum wheat. $491,599. Saskatchewan Agriculture Development Fund/ACIF Matching Funds. 2009-2011. ($46,783).

Listing of Collaborators:

Dr. Danny Singh Wheat Breeder, AAFC-SPARC;
Dr K Kumar, Durum Wheat Breeder, CIMMYT,
Dr. Ron Knox, Biotechnologist, AAFC-SPARC;
Dr. Fran Clarke, Quantitative Geneticist, AAFC-SPARC;
Dr. Jorge Dubcovsky, Wheat Geneticist, U of California-Davis
Dr. Patrick Hayes, Barley Breeder, Oregon State University
Dr. Greg Taylor, Plant Physiologist, University of Alberta
Dr. Dean Spaner, Wheat Breeder, University of Alberta
Dr. Ron DePauw, Spring Wheat Breeder, AAFC-SPARC;
Dr. Doug Brown, Spring Wheat Breeder, AAFC-CRC;
Dr. Gavin Humphreys, Wheat Breeder, AAFC-CRC;
Dr. Nancy Ames, Durum Wheat Quality, AAFC-CRC;
Dr. Jim Dexter, Durum Wheat Quality, GRL, Canadian Grain Commission;
Dr. Ravi Chibbar, Molecular Biologist in Grain Quality, U of S;
Dr. Brian Fowler, Winter Wheat Breeder, Dept. Plant Sciences;

Barley and Oat Breeding and Genetics

Principal Investigator: Brian Rossnagel

Objectives

General Barley and Oat Breeding Objectives

Improved agronomic traits including disease resistance, appropriate maturity, resistance to lodging and shattering, enhanced yield potential, improved stress tolerance.

Improved quality traits to enhance levels of desirable quality parameters, reduce levels of undesirable quality factors and modify chemical composition to foster development of new uses for barley and oat and their components.

Objectives - Barley

Develop new, improved hulled and hulless, two row malting, feed, food and industrial use barley cultivars to maximize and diversify barley productivity in Saskatchewan and western Canada, and to maximize the marketability and value of Saskatchewan and western Canadian barley in domestic and export markets.

Traits for prime consideration will be: high grain yield potential, acceptable maturity, acceptable straw strength and adequate resistance to important barley diseases and shattering. These agronomic parameters must be combined with superior grain quality (malting quality, high test weight and grain plumpness, low hull content, bright colour, peeling and sprouting resistance. low phytate) for maximum marketability. Additional requirements for hulless barley include: food and malt quality, maximizing threshability, minimizing embryo damage, manipulating viscosity and β-glucan, lower phytate, and development of specialty starch and industrial types, including high starch selections.

Sub-objectives

1) Hulled 2R malting
2) Hulled 2R feed
3) Hulless feed for non-ruminants (including low phytate)
4) Hulless food (including waxy, high amylose and normal starch types)
5) Hulless malting

As previously reported we continue amalgamation of 2R hulled malting and feed breeding activities. With the termination of specific industry support for two row hulled feed breeding during 2008 we will begin to significantly reduce our efforts on Hulled 2R feed R&D. While this doesn't mean a complete elimination of feed specific work (crosses made during recent years will be worked through our system to completion) we will now only do feed specific R&D when a unique opportunity presents itself in terms of feed quality. We will continue to derive feed varieties from our malting R&D program when the opportunity arises.

All Barley

Assist in technology transfer regarding barley management and cultivar commercialization to the Saskatchewan and Canadian barley industry.

Introduce and evaluate novel barley germplasm for suitability for use in developing cultivars adapted to Saskatchewan conditions.

Experimental Procedures

Plant breeding procedures using conventional hybridization and several breeding methodologies including a modified pedigree breeding system, single seed descent, molecular marker assisted selection (MMAS), off-season controlled environment facilities and winter nurseries; early generation space-planted bulk nurseries with single plant selection, mid-generation hill-plot and later generation Micro Plot, Preliminary, Standard and regional replicated YTs (yield trials) will be employed. Physical grain quality will be determined using standard laboratory procedures. Chemical quality will be conducted using standard laboratory procedures including Micro-malting using either of the CDC's Joe White or Phoenix micro-malting units, wet chemistry evaluation of resulting green malt, NIR or NIT grain quality analysis, Perten Single Kernel Characterization and Rapid Visco Analysis. Disease resistance evaluations for Fusarium Head Blight, net blotch, spot blotch, scald, true loose smut and covered smut will be conducted in irrigated inoculated field nurseries at Saskatoon and in collaboration with other barley R&D programs utilizing testing sites at Melfort, SK; Brandon and Winnipeg, MB; Edmonton and Lacombe, AB, Ottawa, ON and Charlottetown, PEI. In collaboration with the Crop Molecular Genetics group, Plant Sciences Dept., MMAS will be applied where efficient for loose smut, covered smut, scald, BYDV, net blotch and stem rust resistance. Novel and introduced germplasm will be evaluated for adaptation and utility and increased in standard hill-plot or yield-plot field trials. Breeder Seed and other larger increases will be conducted in accordance with the procedures and regulations of the Canadian Seed Growers Association and the Canada Seeds Act. Technology transfer will be accomplished by cultivar commercialization, field days, written and verbal media communications, individual producer and industry contact, industry meetings and consultation and various modes of professional practice at the provincial, national and international level.

Objectives - Oat

Develop improved milling, feed and industrial use oat cultivars for Saskatchewan to maximize value and marketability in export and domestic markets.

Prime trait targets will be: high grain yield potential, appropriate maturity, acceptable straw strength, adequate levels of disease resistance and superior grain quality for maximum marketability. Quality objectives include: maximum test weight, plumpness, whiteness (brightness), grain size and milling yield and minimum hull, hull acid detergent lignin and groat breakage and combining low lignin hull with high groat fat. Internal chemical quality factors such as protein, fat and β-glucan content are maintained at optimal levels depending on anticipated end-use including selection for combinations of high starch with low fat and protein for industrial use.

Introduce and evaluate novel oat germplasm for suitability for use in developing cultivars adapted to Saskatchewan conditions.

Assist in technology transfer regarding oat management and cultivar commercialization to the Saskatchewan and Canadian oat industry.

Sub-objectives

1) Milling oat including high beta glucan food oat
2) Feed oat including low acid detergent hull high groat fat (LLH-HOG) oat for ruminants and high oil groat oat for non-ruminants
3) Industrial use oat (pending supplemental funding)

Experimental Procedures

Standard plant breeding procedures using hybridization and a modified pedigree/SSD breeding system, including the use of off-season controlled environment facilities and winter nurseries, early generation bulk nurseries with single plant selection, mid-generation hill-plot nurseries, and later generation Micro Plot, Preliminary, Standard and regional replicated YTs (yield trials) will be employed. In collaboration with the Crop Molecular genetics groups in the Plant Sciences Dept. molecular marker assisted selection (MMAS) will be employed to select for crown rust and smut resistance. Physical grain quality will be determined using standard laboratory procedures and chemical quality will be determined using standard laboratory procedures, the NIT 5500 feed quality analyser and the NIRS 6500 grain quality analysis system. Disease resistance evaluations for crown rust will be conducted at Guelph, ON, at the University of Minnesota and at Purdue University; for smut at the University of Minnesota and for BYDV at the University of Illinois and Purdue University. Foreign germplasm will be evaluated for adaptation to Saskatchewan, utility in the breeding program and seed increase. Breeder Seed will be produced in accordance with procedures and regulations of the Canadian Seed Growers Association and the Canada Seeds Act as required. Technology transfer will occur via cultivar commercialization, field days, written and verbal media communications, individual producer contacts, industry meetings and consultation and various modes of professional practice at the provincial, national and international level

Barley & Oat Program Expected Outcomes

Maintained and increased domestic and international marketability (value) of barley and oat products.

Lower cost of production by provision of varieties which produce more product with the same or lower inputs.

Increased probability of successful premium product production (sustainability) via lower production risk due to biotic and abiotic stresses.

Increased possibility for post-harvest value added processing.
Training high quality personnel at the technical and professional levels.
Production of improved and unique germplasm with high value for germplasm exchange - the lifeblood of any breeding program.
Innovation in breeding technology and germplasm development.

Results highlights and notable actions – 01/03/08 to 28/02/09

Variety releases

Barley:
Seven varieties supported for registration and registered!!!

CDC Meredith (TR05104) 2 row malting barley with yield potential 13% > AC Metcalfe (similar to current high yielding feed varieties). It has quality attributes similar to Harrington, AC Metcalfe and CDC Kendall but most important it has consistently been 1% lower in grain protein. Released to SeCan for seed production and marketing.

CDC Reserve (TR05912) 2 row malting barley with similar quality to AC Metcalfe but 7% higher yield, consistently 1% lower grain protein and of most importance improved pre-harvest sprouting tolerance. CDC Reserve comes from our joint breeding project with Sapporo Breweries, Japan and Prairie Malt Ltd. and is the first 2 row malting barley for western Canada with notable pre-harvest sprouting tolerance. Released to SeCan for pedigreed seed production and marketing.

CDC PolarStar (TR06981) 2 row LOXless malting barley which is essentially LOXless CDC Kendall and is from our joint breeding project with Sapporo Breweries, Japan and Prairie Malt Ltd. and is the world's first LOXless variety. CDC PolarStar is of proprietary interest to Sapporo Breweries and, while released to Canterra Seeds for pedigree seed production and distribution, commercialization will be in a closed-loop system managed by Prairie Malt ltd. The LOXless trait positively effects beer foam retention and beer stability thus increasing shelf life and transportability of the product.

CDC Landis (TR05102) 2 row malting barley. Quality similar to AC Metcalfe with 5% higher yield and improved straw strength, physical grain quality and leaf disease resistance. Market testing by P&H with possible release in 2009. If not suitable for the P&H specialty program then CDC Landis will not be commercialized.

HB390 (name *CDC Carter* pending) 2 row smut resistant hulless barley. Essentially CDC McGwire but with genetic resistance to both true loose and surface borne smuts. While of value to all producers, CDC Carter will be of greatest benefit for organic production of hulless barley for food, feed and malt purposes since without fungicide seed treatment economic production of other available hulless barley varieties is essentially impossible. This combination of smut resistance in hulless barley is another first for the CDC program. Released to SeCan for pedigreed seed production and marketing.

TR06389 (name *CDC Austenson* pending) 2 row hulled feed barley with high yield (ranked first in yield across 31 western Canadian sites in the 2006 and 2007 2RCoop trials), good straw strength and physical grain quality, with improved leaf disease resistance in comparison to Xena. Released to SeCan for pedigreed seed production and marketing.

Norman (TR05915) 2 row malting barley which is a joint release with AAFC Brandon where the variety was developed as a more Fusarium Head Blight tolerant version of CDC Kendall. Released to FP Genetics for pedigreed seed production and marketing. This joint release by AAFC, Bdn and the CDC is another first and is a result of our long standing collaboration especially with regard to the extensive AAFC, Bdn FHB screening nursery.

CDC Candle, CDC Alamo, CDC Rattan and CDC Fibar 2 row hulless food barley pedigreed seed marketing rights reallocated. With ending of our food barley R&D agreement with Viterra the CDC was returned marketing rights for these varieties. CDC Candle and CDC Alamo have been subsequently released as public varieties and CDC Rattan and CDC Fibar have been released to Canterra Seeds for pedigreed seed production and marketing.

Oat:

CDC Sol-Fi high beta-glucan specialty milling oat. Marketing rights returned to CDC by Viterra with CDC Sol-Fi subsequently released as a public variety.

Program support changes:

Barley:

SeCan barley R&D support - $120,000/yr, 2008/09 – 2018/2019

SeCan has provided significant support for both our 2 row feed and 2 row malting barley R&D efforts for the past 9 and 10 years respectively. Our joint agreement on malting barley ended during 2008 and that for feed ends during 2009. A new agreement was negotiated during 2008 which will see SeCan provide $120,000 per year for 10 years 2008/09 through 2018/19 for 2 row hulled barley R&D with the primary focus being malting barley R&D.

CWB funding for food barley breeding - $50,000, 2008/09

Cash and in-kind contribution in support of CDC food barley sub-project from Viterra terminated July 31, 2008. CDC has been and is actively seeking alternative funding for this sub-project. Fortunately the Canadian Wheat Board has provided one-year interim funding of $50,000 for 2008/09 to allow us to continue the program during that period while continuing to seek alternative support.

Oat:

QTG Canada/Quaker Oats/PepsiCo funding for oat R&D - $550,000/tr, 2008 through 2010.

Quaker Oats has been funding the CDC oat R&D program for more than 30 years, likely a Canadian record for continued industry/university collaboration. The funding contribution began at a modest $5,000/yr in 1976 and with the negotiation of a new three year agreement (2008 through 2010) during 2008 funding has risen to $550,000 per year. This new agreement sees the funding for the CDC oat breeding project rise from $155,000/yr to $396,000/yr with remaining funds distributed to the CDC oat pathology and the Plant Sciences Oat Agronomy projects. In the breeding project new support will be directed toward general milling oat improvement as ahs been the case for the past 32 years while a significant portion of the new funding will be directed at grain quality items of specific and in some cases confidential and proprietary interest to Quaker Oats.

SODC funding for U of S oat R&D - $100,000/yr, 2008/09 through 2013/14

A five year agreement for a total of $100,000 per year was negotiated between the Saskatchewan Oat Dev Commission and the U of S in support of oat R&D. The funds will be distributed across three U of S oat R&D projects with $34,000 per year to the CDC oat breeding project.

Cargill funding for U of S oat R&D ends 31/12/08

Cargill had been a partner with Quaker Oats for the past 5 years in support of the oat breeding project. That funding ended December 31, 2008.

WGRF Oat FHB project - $50,000/yr, 2009 – 2011.

We successfully applied to the WGRF Endowment fund for support for a project aimed at better understanding Fusarium Head Blight resistance in oat and selection of more FHB tolerant germplasm for the eastern prairie region.

Human Resources:

Dr Aaron Beattie hired as Research Associate - primarily to head up new Oat R&D activities under the new Quaker agreement.

Giselle Camm completed MSc degree and has taken charge of a significant role in overall management of oat and barley quality evaluations.

Loss of two long term members of technical field and quality lab staff (9 and 5 year employees) with considerable difficulty in finding, hiring and retaining replacements for those individuals and other casual staff needs. One new field technician and one new lab technician hired with more needed.

Research Developments:

Oat:

OT3036 milling oat – support for registration requested, Feb., 2009

Over two years testing in the 2007 and 2008 Oat Coop trials, OT3036 combines the high grain yield and straw strength of Morgan with the milling yield of CDC Dancer, larger, plumper grain and a moderate improvement in groat beta glucan and total dietary fibre.

CDC oat lines supported for registration in eastern Canada

As part of our agreement for evaluation of CDC oat breeding lines for eastern Canada with PhytoGene Inc., Ottawa, CDC lines OT3004, SAO1627 and SA03257 were supported for registration in eastern Canada during 2008. In 2009 SO04278 has been supported for registration in Quebec and SO03534 will be released as a forage oat for eastern Canada.

Oat DArT mapping consortium

CDC is a major collaborator in the International Oat DArT (Triticarte Australia) mapping consortium which has developed DArT DNA chip based mapping technology for oat. From this project, in collaboration with Dr. McCartney, CDC, we received our first oat DArT map during 2008 with two other CDC popns currently in Australia for DArT mapping. Of further note is the publication from the consortium project of the peer reviewed article by Nicholas A Tinker, Andrzej Kilian, Charlene P Wight, Katarzyna Heller-Uszynska, Peter Wenzl, Howard W Rines, Ãsmund Bjarnstad, Catherine Howarth, Jean-Luc Jannink, Joseph M Anderson, Brian G Rossnagel, Deon D Stuthman, Mark E Sorrells, Eric W Jackson, Stine Tuvesson, Frederic L Kolb, Olof Olsson, Luiz Carlos Federizzi, Marty L Carson, Herbert H Ohm, Stephen J Molnar, Graham J Scoles, Peter E Eckstein, J. Michael Bonman, Alf Ceplitis and Tim Langdon, 2009, titled "New DArT markers for oat provide enhanced map coverage and global germplasm characterization.", BMC Genomic, January, 2009. This international consortium has now led to the development of a proposed collaborative USDA funded oat genomics project headed by Drs. E. Jackson, USDA, Aberdeen, Idaho and N.Tinker, AAFC, ECORC, Ottawa and the CDC project will be an integral partner in that oat genomics effort.

Oat doubled haploidy

In addition to our collaborative SK ADF project with Alison Ferrie, PBI-NRC (PI) "Double haploidy for oat", in 2008 we received seed of the world's only 2x haploid oat popn in collaboration with MTT and Boreal Plant Breeding, Finland. Working jointly with MTT we will DArT map this unique popn and use it to evaluate new genomics tools recently available for oat R&D.

Expansion of oat yield trial exchanges

2008 saw new oat yield trial exchanges with North Dakota State University and Viterra and the CDC growing trials for the Svalov-Weibull Oat breeding group from Sweden. The exchanges are important to allow our advanced lines to be tested at Watrous, SK and Cassleton, ND and growing all three parties' material at the CDC allows more efficient germplasm resource evaluation.

Joint MSc project with Plant Gene Resources Centre of Canada

Rohit Dhanda from India has joined the project as an MSc student in a collaboration with Dr. A. Diederichsen, PGRCC which houses the world oat germplasm collection. Mr. Dhanda's thesis project aims to evaluate a significant portion of the oat collection and selected CDC breeding materials for fatty acid composition in efforts to improve oat fat quality for food and feed purposes. Initial results are promising with surprising variation for palmitic, oleic, linolenic and linoleic acid in CDC materials.

Barley:

HB402 advanced for support for registration in 2009 - first hulless malting barley variety in Canada and the world.

Our most advanced hulless selection with improved malting quality is HB402. It has completed HBCoop testing and Collaborative Malting trials with support for registration being sought in 2009. If supported Breeder Seed is available and the variety will be released in 2009. Agronomically similar to CDC McGwire, HB402 has improved malt extract and enzymes with lower grain and malt beta glucan.

Malting barley lines to 1st and final year 2009 Collaborative Malting trials

TR07113 and TR07114 completed 2RCoop testing in 2008 and have been advanced to the final year of Collaborative Malting trials in 2009. Both demonstrate good agronomic and disease performance and have malting quality similar to the higher enzyme barley varieties CDC Kendall and Harrington which are especially important for high adjunct brewers in Asia. Pending 2009 malt test results, support for registration and release will be sought in 2010.

TR07116 and TR07117 have been advanced to the final year of the 2RCoop and 1st year Collaborative Malting trials in 2009. Both demonstrate good agronomic and disease performance and have malting quality similar to the higher enzyme barley varieties CDC Kendall and Harrington which are especially important for high adjunct brewers in Asia.

First high amylose hulless lines to 2008 HBCoop

The CDC advanced the first high amylose starch barley selections HB09303 and HB09305 to the 2008 HBCoop. These are a Canadian first and represent a new hulless food type with high beta glucan for high soluble dietary fibre combined with starch made up of approx 40% amylose which should lead to a lower glycemic index food ingredient. HB09305 has been advanced to final year 2009 HBCoop and could be considered for support for registration in 2010.

Selection for fermentability (collaboration with A. Speers, Dalhousie Univ and M. Edney, GRL-CGC)

Working with Dr. A. Speers, Dalhousie University to attempt to develop an effective small scale screening capability for fermentability since this is the ultimate value of barley malt in brewing. We have received support for portions of this larger project from SK ADF and the BMBRI and plan to again jointly submit an application for NSERC Strategic funding for this project.

New grants received and projects initiated or altered include:

- new 3 year WGRF agreement in support of the CDC Oat FHB sub-project ($150,000 over three years, 2009 - 2011.
- new 5 year agreement with SODC in support of oat R&D. $100,000/yr (with $34,000/yr to CDC Breeding project), 2008/09 – 2003/14
- new 1 year grant-in-aid from BMBRI in support of malting barley limit dextrinase project. $20,000, 04/08 – 03/09.
- new 2 year SK ADF project in support of malting barley fermentability association mapping project. $44,000/yr, 2009 – 2010.
- negotiated 3 year extension of milling oat R&D agreement with QTG-PepsiCo/Canada. $396,000/yr to breeding project of total project of $550,000/yr, 2008-2010.
- negotiated 10 year extension of the SeCan agreement in support of 2R barley R&D. $120,000/yr, 2008/09 – 2018/19.
- participation in several other new separately funded programs from the SK ADF and other industry players with other collaborators as PIs.

Results as per Expected Outputs

Barley

- up to 80 new crosses made

81 crosses attempted/80 successful. 4 forage, 66 malt, 4 feed and 7 food crosses made during summer 2008 with resulting F1s increased in 2000/09 NZ winter nursery

- F2 bulks and F4 space planted bulks grown with selection, F5 and F6 hill plots grown with selection, F6 – F9 MicroPlot yield trials and regular yield plot trials grown with selection

91 F2 bulk popns planted, maintained and bulk harvested, cleaned and sized with seed from 81 sent to 08/09 NZ nursery as F3 bulks

15 F3 bulk popns planted, maintained and bulk harvested, cleaned and sized with seed for 14 2009 space planted F4s popns at Saskatoon.

90 F4 and 18 F5 space planted popns grown and maintained with 300-400 single head selected from 80 popns. Single heads threshed and visually selected for physical grain quality with some 13,000 to be selected and grown as single F5 hill plots in 2009.

13,938 F5 selections from 116 popns grown and maintained as individual hill plots and selected among in the field (approx 50%). Following harvest these 7500 selections were cleaned and are being evaluated for grain quality. Approximately 3000 will be advanced to 2009 MicroPlot Yield trials (YTs)

7968 F5 RIL (SSD) selections from 40 popns grown and maintained as individual hill plots and selected among in the field (approx 50%). Following harvest these 4000 selections were cleaned and are being evaluated for grain quality. Approximately 1500 will be advanced to 2009 MicroPlot YTs.

2373 F6 selections from 20 popns grown and maintained as individual hill plots and selected among in the field (approx 50%). Following harvest these 1000 selections were cleaned and are being evaluated for grain quality. Approximately 300 will be advanced to 2009 MicroPlot YTs.

2131 F6 and F7 selections evaluated in Preliminary MicroPlot YTs (544 hulless food, malt and feed, 539 hulled feed and 1020 hulled malt). 1102 field selected (275 hulless, 271 feed and 542 malt) and harvested with post-harvest physical and chemical grain quality analysis and micromalting when appropriate. Some 600 selections to be advanced to 2 rep x 1 or 2 site Preliminary YTs in 2009.

934 selections (411 malt, 165 hulless food/malt, 346 feed, 12 forage) evaluated in Preliminary YTs (2 reps at 2 sites). Following post-harvest physical and chemical data collection with 200 best selections advanced to 3 rep multi-site 2009 Standard YTs.

224 advanced selections evaluated in 3 rep Standard YTs at 5 or 6 sites. All harvested with post-harvest chemical and physical grain quality analysis and micromalting when appropriate. Best selections advanced to 2009 2R Coop (7), HBCoop (6) or EPB (14) YTs with some selections to be re-tested in 2009 CDC Standard YTs.

5 entries evaluated for forage yield and quality in 3 rep trial at 3 sites. Two selections to be advanced to 2009 Forage Barley Coop. 12 entries evaluated for forage yield and quality in 2 rep trial at 2 sites. Two selections to be advanced to 2009 forage evaluation trials.

- Bulk and special increases grown and processed for R&D seed supplies and collaborative food and feed barley evaluations
- 53 - 0.01 acre Bulk Increases planted, maintained, harvested, cleaned and stored. 200 head selections taken for Breeder Seed purification from appropriate 1st year Coop entries.
- 41 - 0.004 acre Bulk Increases planted, maintained, harvested, cleaned and stored.

- Foreign introductions grown and evaluated in hill or yield plots

13 CIMMYT lines in hill plots
53 new Australian advanced breeding lines in multiple hill plots
Foreign YTs grown – USDA MVBN, WRSBN

- Up to 1000 accessions increased for Plant Gene Resources Centre of Canada

Done

- two malt (TR07113 & TR07114) and one feed (TR07393) final year and four malt and three feed first year hulled entries plus one final year (TR07921) and three first year joint CDC/Sapporo/PML malt entries in 2008 2R Coop.

TR07113, TR07114 and TR07921 advanced to 2nd year 2009 Collaborative Malting trials and may be considered for support for registration in 2010. TR07393 dropped from testing.
1st year malt entries: TR08116, TR08117, TR08800 adv to final year 2009 Coop and 1st year 2009 Collaborative Malting trials, TR08115, TR08118, TR08801 and TR08802 dropped.
1st year feed entries: TR08395 adv to final year 2009 Coop trials. TR08394 and TR08396 dropped.

- two first year (TR07113 & TR07114) 2R malt entries and one first year (TR07921) joint 2R malt entry with Sapporo/PML in 2008 Collaborative Malting trials.

All three advanced to 2nd and final year 2009 Collaborative Malting Trials

- two 2R hulless food entries (HB396 and HB398) in final HBCoop.

Both dropped from further testing.

- seven 2R hulless entries in first year 2008 HBCoop (one general purpose, two malt, two high-amylose food and two waxy food.

HB08301 (malt), HB08304 (malt) and HB08305 (high amylose) adv to final year 2008 HBCoop.
All four other entries dropped.

- One second year entry (HB402) in 2008 Collaborative Hulless malting trial.

HB402 hulless malt barley being proposed for support for registration.

- Up to fifteen malt, feed and hulless entries in 2008 Eastern Prairie Barley trial

6 malt and 4 feed lines tested with SB050499 (feed) and SB040462 (feed) advanced to 1st 2009 2RCoop. Entry SSP060051 (malt) to be tested in 2009 CDC trials. Remaining 7 entries dropped.

- Breeder Long Rows of TR06389 and HB390 produced

TR06389 feed – 200 Breeder Long Rows planted with 33 discarded during purification. 499 kg cleaned Breeder Seed at 97% germination produced and stored.
HB390 hulless – 200 Breeder Long Rows planted with 13 discarded during purification. 549 kg cleaned Breeder Seed at 99% germination produced and stored.

- Breeder hills of five final year Coop entries (TR07113, TR07114, TR07921, HB396 and HB398) produced

200 paired Breeder hills of TR07113, TR07114, TR07921, TR07393, HB396 and HB398 planted, maintained, rogued, harvested and stored. Those from TR07393, HB396 and HB398 will be discarded. Those from TR07113 and TR07114 will be used for 2009 Breeder long row and Breeder Seed production in anticipation of registration in 2010.

- Breeder Seed production of TR05102, TR05104, TR05912 and TR06918.

CDC Landis (TR05102) – not grown in 2008.
CDC Meredith (TR05104) – 4132 kg clean Breeder Seed purified, produced, processed and stored. 99% germ.
CDC Reserve (TR05912) – 1349 kg clean Breeder Seed purified, produced, processed and stored. 98% germ.
CDC PolarStar (TR06918) – not grown in 2008.

- Breeder Seed production of older malt, feed and food barley varieties as required.

None required in 2008.

- Special 0.5 - 2.5 acre increases of new varieties/advanced lines as required for collaborative malt, feed and food quality testing and for market development work when appropriate.

CDC Reserve (TR05912 malt – 1 acre grown with 1536 kg clean seed produced and stored
TR08800 malt – 1 acre grown with 1366 kg clean seed produced and stored
HB396 hulless food – 0.25 acres grown with 304 kg clean seed produced and stored
HB398 hulless food – 0.25 acres grown with 450 kg clean seed produced and stored
CDC Fibar – 0.3 acres grown with 600 kg clean seed produced and stored
SB90300 – 0.3 acres grown with 625 kg clean seed produced, stored and provided to Pr Swine Center for swine nutrition study.
SB90354 – 0.3 acres grown with 575 kg clean seed produced, stored and provided to Pr Swine Center for swine nutrition study.
SB94893 – 0.3 acres grown with 550 kg clean seed produced, stored and provided to Pr Swine Center for swine nutrition study.
SR93139 – 0.3 acres grown with 550 kg clean seed produced, stored and provided to Pr Swine Center for swine nutrition study.

- Collaborative 2R, 6R and Hulless Malting barley increases produced under special low-protein agronomy management.

19 entry (8 two row, 7 six row and 4 hulless) Collaborative malting trials grown at one site specifically managed to produce low protein barley. CDC and joint entries included TR07113, TR07114, TR07921 and HB402. Samples successfully produced with average grain protein just over 10%. 19 Samples provided to BMBRI and used for pilot malting trials at industry and GRL labs.

- Grow sites of 2R Coop, 6R Coop, Hulless Coop, Forage Coop pre-registration trials, Eastern Prairie Barley pre-Coop trial and exchange yield trials with AAFC, Brandon; AAFRD, Lacombe and Busch Ag Res Inc.

Coop Trials – HBCoop (25 entries x 3 reps x 2 sites); 2RCoop (35 entries x 3 reps x 2 sites); 6RCoop (25 entries x 3 reps x 1 site), EPB trial (36 entries x 3 reps x 2 sites); FBCoop (13 entries x 4 reps); FBCoop grain (16 entries x 3 + 4 reps).

- Disease nursery evaluations for loose and covered smut, net and spot blotch, scald and FHB

Saskatoon leaf disease (spot blotch) nursery – 7397 CDC entries + 1662 collaborator entries
Melfort net-form net blotch and spot blotch nursery – 6335 CDC entries + 1547 collaborator entries.
Saskatoon loose smut nursery – 2282 entries inoculated with 1231 harvested and test grown in GH.
Saskatoon covered smut nursery – 382 entries
Lacombe scald nursery – 1825 entries
Lacombe common root rot nursery – 148 entries
AAFC Brandon leaf disease nursery – 1250 entries
AAFC Bdn FHB nursery – 4000 entries
AAFC Ottawa FHB nursery – 300 entries
AAFC Charlottetown FHB nursery – 300 entries
AAFC Portage la Prairie FHB nursery – 300 entries
MMAS for Un8 smut, Rpg1 stem rust – > 1000 lines evaluated for molecular markers associated with the Un8 loose smut resistance gene or the Rpg1 stem rust resistance gene.
Participated in USDA NABSEN FHB nursery. Two CDC entries.

- Up to 30 populations processed through single seed descent

31 popns processed through F3 and F4 SSD and 4popns through F4 and F5

- F1s and F3s increased in NZ winter nursery as well as other increases as required

109 F1, 114 F3 & 15 F4 popns increased 2007/08 NZ winter nursery

- Other activity associated with breeding program

SVPG Regional Barley YT – 25 entry x 3 rep Sask. regional YT grown at 1 site

AAFC Bdn exchange trials – 15 trials at 1 or 2 sites
AAFRD Lacombe exchange trials – 6 trials
Busch Ag Resources exchange trials – 2 trials x 2 sites
USDA YTs – MVBN, WRDSBN
2RBarVYT – 25 entries x 3 reps x 6 sites
RVABYT – 30 entries x 1 reps
PhytMB – 8 entries x 16 reps x 2 sites – collab low phytate malt barley trials with Legge (AAFC Bdn) and Edney (GRL,CGC)
SGL108A – 60 entries x 3 reps - collab malt barley dormancy trials with Legge (AAFC Bdn) and Edney (GRL,CGC)
SKCS project

- B/M RILMP – 284 CDC Bold x McLeod RILs

Malt BG project – 112 CDC Bold x CDC Copeland RIL MicroPlots
MMAS for crossing block parents – all new parents used in the 2008 crossing program were characterized for molecular markers available for screening.
Herbicide screening evaluation – all final year 2RCoop and HBCoop entries evaluated for rxn to 2x rates of all registered barley herbicides and tank mixes (collab with F.A. Holm).
Screened all advanced selections for presence of Rpg1 stem rust resistance gene using molecular markers.
DArT mapping projects

- BelzDArT YT – 46 entries x 2 sites – collab Association Mapping project with U of Laval
- 251/B RIL YT – 263 entries TR251 x CDC Bold
- D/251 DArT YT – 120 entries CDC Dolly x TR251 2x haploids

Fermentability project (collab with Speers (Dalhousie) & Edney (GRL, CGC)
- SpeersBYT – 16 entries x 3 reps x 2 sites

MiscBYT – 12 entries, advanced breeding lines from Boreal Plant Breeding, Finland.
BISONBYT – 14 entries, stripe rust project collab with Hayes (OSU)
4x hill increase of 65 CDC Kendall x Kinai Kyoshinkai-2 RILs for starch granule size project (collab with Chibbar)
Hill plot increase 152 TR05384 x Laural special scald resistance popn
4x hill plot increase 92 lines for 2RCoop Association Mapping project
Increase of 9 very high SKCS (hard) lines from PCRCC collection

- Pending PRCOB support for registration initiate and complete registration and variety release for TR05102, TR05104, TR05912 and TR06918 malt barley, TR06389 feed barley and HB390 hulless barley.

TR05102 supported and registered as CDC Landis – possible release to P&H Ltd.
TR05104 supported and registered as CDC Meredith – released to SeCan.
TR05912 supported and registered as CDC Reserve – released to SeCan.
TR06918 supported and registered as CDC PolarStar – released to Canterra Seeds.

- complete PBR for CDC Lophy-I, CDC Mindon and TR06918

PBR granted for CDC Mindon and CDC PolarStar (TR06918). CDC Lophy-I submitted and pending.

- Pending PRCOB support for registration, initiate PBR for HB390, TR06389, TR05102, TR05104 and TR05912.

PBR process initiated for all 5 varieties.

- provide progress or final reports to outside funding agencies: Agricore United (hulless food barley); SeCan (2 row hulled feed barley), WGRF Barley Check-off, Sask Ag & Food re CDC SRP project, ADF FHB screening project, ADF net blotch project, CDC/Sapporo/PML 2 row malt barley project, SeCan 2 row malt barley project, ADF Spot blotch project, P&H Malting barley project

All done. ADF net blotch project and SeCan 2 row malt barley project reports were final reports.

- Continue collaborations with local, regional, national and international barley breeders, pathologists, molecular biologists, grain quality scientists and animal nutritionists

All done.

- Continue special projects – molecular characterization for variety ID, low phytate, net blotch MMAS, spot blotch MMAS, Rpg1 stem rust MMAS, Un8 loose smut MMAS, covered smut MMAS, annual parental marker screening, NIR for DON detection, NIR for hull measurement, NIR for beta glucan measurement, NIR for malting quality screening, FHB field screening, coloured hulless, RVA and pre-germination, DArT mapping for MMAS, sprouting tolerance (with Legge), 6R malt breeding (with Harvey & BARI), special food barley project (with Sapporo), hulless malt (with Edney), hulless food (with Ames (AAFC, CRC), Izydorczyk & Dexter (GRL, CGC) and others), lower protein, low anthocyanin hulless, grain hardness, low phytate malt (with Legge and Edney), barley beta glucan (with Chibbar and Izydorczyk), starch granule size (with Chibbar), barley husk quality (with Yu), Sapporo specific malt barley (with Sapporo and PML), Hordeum spontaneum disease resistance introgression (with Steffenson), low phytate hulless evaluation (with CWB & U of Man.), annual forage (with B. Coulman), 2R malt barley development for P&H, association mapping project for 2R malting quality, limit dextrinase project (BMBRI funding), low protein MMAS (with T. Blake, MSU), stripe rust screening (with P. Hayes, OSU)

All done with special food barley project (with Sapporo), barley husk quality (with Yu) and Hordeum spontaneum disease resistance introgression (with Steffenson) and covered smut MMAS projects completed.

- Continue integration with new CDC cereal and flax pathology program (McCartney)

Dr. McCartney has declined involvement with the CDC barley pathology activities.

- Applications for supplemental funding to various agencies

One year 2008/09 interim-funding ($50,000) from CWB to maintain hulless food barley development project.
Multiple LOIs submitted to SK ADF – one project (Assoc mapping for malt quality) for full proposal – successful
Extended multi-year 2R malt barley R&D agreement with Sapporo/PML.
Successful collab application to BMBRI with Speers (PI) & Edney re malt fermentability.
Participant in several other applications and successfully funded projects as collaborator

- Continue to re-negotiate funding agreements for 2R hulled feed and malt barley with SeCan.

Negotiated new 10 year 2R barley R&D agreement with SeCan.

- Search for supplemental funding for specialty starch hulless food barley development.

1 yr interim funding from CWB with search for longer term funding continuing

- Attend and participate in appropriate barley R&D meetings

Multiple meetings attended – PRCOB, NFS, CFIA, CSGA, SSGA, CWB, CFIA, SVPG, ASBC/WBC, Sapporo/PML, USDA-BarleyCAP, AMBA, CIGI, CMBTC (as BoD member), WGRF, AWB (as BoD Member), FII, NABRW, ACIDF/ABC, BDC, etc.

- Initiate new special projects with or pending supplemental funding - fermentability project (with A. Speers, Dalhousie & M.Edney, GRL); Ug99 stem rust screening (with T. Fetch, AAFC, CRC), food barley R&D, association mapping, hulless for malt, and other opportunities.

All underway although no new funds in place for Ug99 stem rust or hulless malt projects and only very short term funding found for hulless food and assoc mapping projects.

Oat

- up to 35 new crosses made

60 crosses attempted with 51 made in two crossing blocks with all F1s grown in greenhouse

- F2, F4 and F5 bulks grown with selection, F5 and F6 hill plots grown with selection, F6 – F9 multiple hill plots, microplots and yield plots grown with selection

26 F2 and 22 F3 bulks planted, maintained and bulk harvested, cleaned and sized with seed to NZ for F3 and F4 winter increase as bulk popns for 2009 F4 and F5 space planted nurseries.

31 F4 and 14 F5 space planted bulks, planted and maintained with single plant selections taken for advance to 2009 F5 and F6 hills at Saskatoon

1144 F4 SSD lines from 7 popns planted and maintained with 663 selected and being grown as F5 hills in 08/09 NZ winter nursery with some 500 selected to be grown in 2009 F5 SSD hills at Saskatoon

9,522 selections in hill plots - 4798 F5 selections from 33 popns, 1912 F5 RILs (SSD) selections from 10 popns, 2416 F6 selections from 17 popns and 396 F6 RILs (SSD) selections from 2 popns - grown and maintained as hill plots with approximately 50% field selected and harvested. Following visual and chemical seed quality evaluation 1086 have been advanced to 2009 MicroPlot YTs

2285 selections evaluated in MicroPlot YTs with 1251 field selected and harvested. Following extensive physical and chemical seed quality evaluation some 300 selections will be advanced to 2009 2 rep 1 or 2 site Preliminary YTs.

267 selections evaluated in 2 rep Prelim YTs at 2 sites with 69 selections advanced to 2009 multi-site Standard YTs.

79 advanced selections evaluated in 3 rep Standard YTs trials at 6 sites across western Canada with best selections advanced to 2009 WCoop (6) and RAT (7) trials or re-tested in 2009 CDC Standard YTs (1).

- Bulk and special increases grown and processed for R&D seed supplies and collaborative food and feed barley evaluations

0.3 acre increase of OT3031 grown with 660 kg produced, cleaned and stored. To e provided to PhytoGene Resources, Ottawa for market development activity in eastern Canada.

Twenty-one 0.01 acre Bulk Increases acre Bulk Increases planted, maintained, harvested, cleaned and stored. 200 head selections taken for Breeder Seed purification from appropriate 1st year Coop entries.

Twelve 0.03 acre Bulk Increases planted, maintained, harvested, cleaned and stored with 35 kg samples of each entry provided to Quaker Oats for specialty milling and food product quality evaluations.

15 - 0.004 acre Bulk Increases planted, maintained, harvested, cleaned and stored.

- Foreign introductions grown and evaluated in hill or yield plots

100 entry Quaker Int'l nursery grown in hill plots

10 special LSU crown rust resistant selections grown in 4x hill plots.
197 RILs from IGER (Wales) cross 02-177CnIII for BG and DArT mapping projects
MiscOYT – 25 entries from Wales and Finland
PIOIMP – 360 entry MicroPlotYT – Int'l DArT association popn (collab with Tinker (AAFC, ECORC)
Aslak x Matilda 2x haploid oat popn (Finland) – 154 entries – DArT mapping project
2006 & 2007 QION selections – 78 MicroPlotYT

- three final year (OT3031, OT3033 and OT3036) and six first year milling/feed entries (OT3037, OT3038, OT3040, OT3041, OT3042 & O3044) in WCoop Oat trial

OT3036 – requesting support for registration and release
OT3031and OT3033 dropped from further testing in western Canada
OT3037 and OT3044 advanced to final year 2009 Coop trials with others dropped from further testing in western Canada.

- two first year LLH-HOG entries (OT3039 & OT3043) in WCoop Oat trial

OT3039 adv to final year 2009 Coop trials. OT3043 dropped.

- five milling/feed entries in Rust Area Trial

SO04445 adv to 1st year 2009 WCoop trials. Others dropped.

- Breeder hills of three final year Coop entries produced

200 Breeder hills of each of OT3031, OT3033 and OT3036 planted, maintained, rogued, harvested and stored for 2009 Breeder Long Rows. OT3031 will be provided to PhytoGene Resources, Ottawa, pending support for registration OT3036 will be grown as 2009 Breeder Long Rows and OT3033 will be discarded.

- No Breeder Long rows in 2008

None grown

- Produce Breeder seed of CDC Minstrel

0.75 acre increase of CDC Minstrel planted, maintained, and rogued with 1045 kg Breeder Seed at 99% germination produced, cleaned and stored.
0.5 acre increase of CDC ProFi planted, maintained, and rogued with 475 kg Breeder Seed at 99% germination produced, cleaned and stored.

- Special 0.5 acre increases of new and special quality selections as required for collaborative feed and food quality testing and for market development work when appropriate.

0.5 acre increase of OT3031 planted, maintained, and rogued with 660 kg seed produced, cleaned and stored.

- Disease nursery evaluations conducted for smut, crown rust and BYDV

University of Minnesota slow rust nursery – 1000 selections tested for slow rusting and BYDV. Data of limited value due to low rust and BYDV infection.

Guelph crown rust nursery – 2012 selections evaluated. Good selection for rust resistance not related to Pc68 resistance with several potential unique sources of resistance to new crown rust race identified or confirmed and several sources showing evidence of breakdown during 2008.

U of S crown rust nursery – 99 CDC lines tested with limited results due to poor disease development.

99 CDC entries in 2008 Quaker Eastern (Canada) Rust Nursery with 11 selections showing good non-Pc68 resistance at Navan and only a few entries carrying Pc91 showing resistance at Lindsay.

21 CDC entries in 2008 USDA slow crown rust nursery with CDC entries among the best performers and 11 re-entered for 2009.

Illinois BYDV testing – 200 lines tested. Good data received with 5 CDC selns showing very good tolerance and 17 showing tolerance.

Univ of Minnesota smut nursery – 1000 lines tested. Good data received.

- Up to 20 populations processed through single seed descent

34 popns being processed through F2/F3, F3/F4 or F4/F5 SSD

- F1s increased in greenhouse

51 F1s grown in CDC greenhouses

- existing F2s, F3s and F4s increased in NZ winter nursery

29 F2, 26 F3 and 22 F4 bulk popns plus 951 F5 hills from seven SSD popns growing in 2008/09 NZ winter nursery

- continue or initiate PBR procedures for CDC Sol-Fi, CDC ProFi, CDC SO-I and CDC Minstrel

PBR issued for CDC Sol-Fi
CDC SO-I and CDC Minstrel applied for and in process
Not possible to apply for CDC ProFi

- provide progress or final reports to Quaker Oats Canada, Quaker/Pepsico and Cargill; the general oat milling industry, SuperOats Canada, Sask ADF re CDC project.

All done

- Continue collaborations with local, regional, national and international oat breeders, pathologists, molecular biologists and grain quality scientists.

In progress

- Continue special projects – e.g. LLH-HOG oat, high groat fat oat, high beta glucan oat development, collaboration with PhytoGene Resources, participation in eastern Canada Quaker Rust Nursery, collaboration with A. Ferrie, PBI and MMT and Boreal Plant

Breeding, Finland re oat double haploidy, oat EST project with PBI, international oat DArT mapping project, collaboration with Plant Res NZ.

Joint MSc project with Plant Gene Resources Centre of Canada - Rohit Dhanda has joined the project as an MSc student in a collaboration with Dr. A. Diederichsen, PGRCC. The thesis project aims to evaluate a significant portion of the oat collection and selected CDC breeding materials for fatty acid composition.

Coop and other collab trials – WCoop, RAT, WPAT, NDSU YTs, Viterra YTs and SW YTs planted, maintained, harvested with post-harvest data collected and grain samples provided to collaborators from further quality evaluations.

(QuObs) Quaker Observation Nursery – coordinated this 100 entry 3 site 1 rep Canada and USA trial and grew one site. 19 CDC entries.

QION – Quaker Int'l Oat Nursery – 100 entries x 1 rep hill plots. Several VG lines for further evaluation from Argentina and Chile.

SVPG Regional Oat YT – 12 entry x 3 rep Sask. regional oat YT grown at 1 site

Secondary metabolites (Avenanthramide) projet
- Gem/Profi YT – 105 entries x 1 rep planted, maintained, harvested and post-harvest data collected.
- W/VRILYT – 178 entries x 1 rep planted, maintained, harvested and post-harvest data collected.
- Kaufmann x OT380 – 155 entries in MPYTs
- Ajay x OT399 – 165 entries x MPYTs

Beta glucan and TDF project
- TDF/BGOYT – 18 entries x 3 sites
- BGOYT# 1 - 16 entries
- BGOYT# 2 – 40 entries
- Furlong x CDC Sol-Fi 4x hills – 191 entries
- CDC Sol-Fi x HiFi 2x hills – 102 entries
- CDC Dancer x CDC ProFi 2x hills – 164 entries

FORYT (Forage oat yield trials) – collab with Coulman
- 2008 FORYT - 16 entries by 3 reps at 3 sites planted, maintained, harvested and post-harvest data collected.
- 2008 POForYT – 10 entries x 2 reps x 2 sites planted, maintained, harvested and post-harvest data collected.

MMAS for crossing block parents – all new parents used in the 2008 crossing program were characterized for molecular markers available for screening.

Herbicide screening evaluation – all final year WCoop entries evaluated for rxn to 2x rates of all registered oat herbicides and tank mixes (collab with F.A. Holm).

Svalov-Weibull Oat YT – 16 entries x 3 reps planted, maintained, harvested and post-harvest data collected.

NDSU exchange Oat YTs – 1 x 36 and 1 x 25 entries x 3 reps planted, maintained, harvested and post-harvest data collected.

Viterra exchange Oat YTs – 5 x 36 entries x 3 reps planted, maintained, harvested and post-harvest data collected.

USDA Slow rusting project – 7 entry special 4x hill increase

- Applications for supplemental funding to various agencies

Developed 2008/09 thru 2013/2014 oat R&D funding agreement with Sask Oat Dev Comm for $100,000 per year with $34,000/yr for the CDC oat breeding project.
LOI and full proposal to WGRF re oat FHB project – successful
Four LOIs to ADF (oat for ethanol; oat and flax trialing in eastern SK; oat FHB; oat mutagenesis) – one (oat mutagenesis) to full proposal stage – not successful.

- Continue negotiation of Quaker Quality Oat project funding with Quaker Oats and Cargill

Successfully negotiated new 2008 – 2010 agreement with QTG Canada/Quaker Oats/PepsiCo with major funding increase.
Cargill funding terminated Dec 31, 2008

- Continue negotiation with SODC for oat project R&D support

Successfully negotiated 2008/09 thru 2013/2014 oat R&D funding agreement with Sask Oat Dev Comm for $100,000 per year with $34,000/yr for the CDC oat breeding project.

- Establish R&D linkage with University of Gothenburg, Sweden re mutagenesis and TILLIING

In progress with initial germplasm exchange underway

- Attend and participate in appropriate oat R&D meetings

Multiple meetings attended – PRCOB, NFS, CFIA, CSGA, SSGA, CFIA, SVPG, CIGI, SODC, POGA, AWB (as BoD Member), FII, IOC, Quaker, Swedish Oat Assoc, etc.

Collaborations:

CDC – PLANT SCIENCES Dept. U of S

Dr. B.L. Harvey (Professor Emeritus)
Professor
Malting Barley Breeding

F.A.Holm
Professor
Weed Science

Dr. G.J. Scoles
Professor
Barley Biotechnology

Dr. C. McCartney
Assistant Professor (CDC)
Cereal Pathology

Dr. S. Shirtliffe
Assoc. Professor
Agronomy

Dr. R. Chibbar
Professor & CRC
Mol Biology

ASSOCIATED RESEARCHERS AT UNIVERSITY OF SASKATCHEWAN:
Department. of Animal & Poultry Science:
Dr. H. Classen, Poultry Nutrition
Dr. J. McKinnon, Beef Nutrition
Drs. D. Christensen (Prof. Emeritus) and A. VanKessel, Dairy Nutrition
Dr. P. Thacker, Swine Nutrition
Dr. P. Yu, Feed Innovation Institute
Department. of Applied Microbiology & Food Science:
Dr. R. Tyler, Cereal Chemist
Plant Gene Resources Centre, Agriculture and AgriFood Canada Research Centre:
Drs. K. Richards, A. Deidreichsen & YB Fu
Prairie Swine Centre:
Drs. P. Leterme and R. Pieper
Plant Biotech Institute:
Dr. A. Ferrie

INDIVIDUALS and AGENCIES OUTSIDE SASKATOON:
Pathology:
Drs. A. Tekauz, J. Chong, T. Fetch, J. Menzies, J. Gilbert & S. Haber, CRC-AAFC Winnipeg
Dr. B. Steffenson, R. Dill-Macky, Univ. of Minnesota
Mr. J. Tucker, AAFC, Brandon
Dr. D. Falk, U of Guelph
Dr. A. McElroy, PhytoGene Resources, Ottawa
Dr. K. Turkington, AAFC, Lacombe
Drs. K. Xi, FCDC, Lacombe
Dr. R. Martin, AAFC, Charlottetown
Dr. L. Skoglund, BARI, Fort Collins, USA
Quality:
Drs. M. Edney, M. Izydorczyk & J. Dexter, CGC-GRL, Winnipeg
Dr. N. Ames, CRC-AAFC, Winnipeg
Dr. S. Miller, AAFC, ECORC, Ottawa
Drs. Y. Li, R McCaig, CMBTC, Winnipeg
M. Brophy, BMBRI, Winnipeg
Dr. V. Raboy, USDA-ARS, Aberdeen, Idaho
Drs. T. Vasanthan, Univ. of Alberta
Dr. P. Wood, AAFC, Guelph
Dr. K. Swallow, Food Res Centre, Leduc, AB
Dr. A. Speers, Dalhousie Univ, Halifax, NS
D. Munro, Canadian Wheat Board Market Dev. Branch, Winnipeg, MB
Sapporo Breweries, Japan
InfraReady Products Ltd., Saskatoon.
Breeding & Biotech:
Canada:
Drs. W. Legge & M. Therrien, AAFC Brandon Res. Centre
Drs. J. Helm, P. Juskiw, J. Nyachiro and D. Salmon, FCDC, Lacombe
Dr. A. McElroy, PhytoGene Resources, Ottawa

Drs. W. Yan and N. Tinker, ECORC, AAFC, Ottawa
Dr. F. Belzile, U of Laval
Dr. Jennifer Mitchell-Fetch, CRC, AAFC, Winnipeg
Jim Anderson, T. Ferguson, Viterra, Calgary
K. Hanson, Viterra, Watrous, SK
FP Genetics, Regina
Canterra Seeds, Winnipeg
SeCan, Ottawa
P&H Ltd, Winnipeg
InfraReady Products, Saskatoon
Foreign:
Drs. K. Smith, D. Stuthman U. of Minnesota
Drs. R. Horsley and M. McMullen, NDSU, Fargo
Dr. D. Clark, Western Plant Breeders, Bozeman
Drs. B. Cooper and G. Hanning, BARI, Fort Collins, USA
Dr. T. Blake, Montana State Univ., Bozeman
Drs. S. Ullrich & A. Kleinhoffs, Washington State Univ., Pullman
Dr. P. Hayes, Oregon State Univ., Corvallis
Drs. P. Bregitzer, D. Obert, M. Bonman, USDA-ARS, Aberdeen, Idaho
Dr. H. Bockleman, USDA-ARS, Aberdeen, Idaho
Dr. H. Ohm, Purdue University
Dr. F. Kolb, University of Illinois
Dr. H. Kaeppler, University of Wisconsin
Dr. R. Barnett, University of Florida
Dr. S. Harrison, Louisiana State Univ
Dr. J. Frankowiak, QDPI, Warwick, Aust.
Dr. J. Eglington & A. Box, Waite Inst., Adelaide, Aust.
Drs. R. Lance & C. Li, West. Aust. Department. of Ag., Perth, Aust.
Drs. W. Thomas and R. Waugh, Scottish Crop Res. Inst., UK
Dr. R. Pickering, C&FR, Lincoln, NZ
Dr. P. Zwer, SARDI, Adelaide, Australia
W. Saito, T. Hoki, Drs. S. Takahashi and S. Ito, Sapporo Breweries, Japan
Dr. A. Cepitlis Svalof Weibull Ltd., Sweden
Dr. O. Olsson, Univ of Gothenburg, Sweden
Boreal Plant Breeding, Finland
IGER, Oat breeding, Wales
Numerous other barley and oat breeders in the EU

Funding Sources: (PI is first listed)

Annual funds 2007-08 (* = New in 2007-08):

*A. Speers, M.Edney, B. Rossnagel. Fermentability determination of Canadian barley. $21,750. Brewing and Malting Barley Research Institute, 2008/09.

B.G.Rossnagel. Grant-in-aid for breeding oat for greater fat content. $25,000. Saskatchewan Oat Development Commission, 2007/08.

*B.G.Rossnagel, A. Beattie, T. Zatorski. Identifying single nucleotide polymorphisms in Canadian two-row malting barley associated with higher limit dextrinase activity and lower limit dextrinase inhibitor levels. $20,000. Brewing and Malting Barley Research Institute, 2008/09.

* A. Speers, M.Edney, B. Rossnagel. Mash unit for fermentability determination of Canadian barley. $20,000. Brewing and Malting Barley Research Institute, 2007/08.

P. Leterme et al, including B.G.Rossnagel. Alternative feedstuffs for reducing ammonia and odor emissions in pork production systems and improving the pig's gut health. $40,000. National Pork Board, January 2007 - April 2008.

B.G.Rossnagel, Grant-in Aid of CDC Oat R&D, $15,000, Grain Millers Inc. 2007/08, ongoing since 2005/06.

B.G. Rossnagel, Grant-in-Aid of CDC Oat R & D, $15,000, Can Oat Milling Ltd., 2007-08, ongoing since1997/98.

B.G. Rossnagel, Oat Breeding and Research, $15,500, Quaker Oats of Canada Ltd., 2007-08; ongoing since 1976.

K. Turkington, J. Helm, B. Rossnagel and K. Xi, Screening for Scald Resistance for Future Alberta Variety Barley Varieties, $30,000, Alberta Barley Commission and AARI, 2007-08.

W.Legge, M.Edney, B.Rossnagel, R.McCaig, P.Juskiw. Effect of reduced phytate content on malting and brewing quality. Brewing and Malting Barley Research Institute. $15,000, 2007/08.

B.L.Harvey and B.G.Rossnagel. 6-row Malting Barley R&D. $US99,250. Busch Agricultural Resources Inc., 2007/08.

Multi-year grants/contracts which include the 2007-08 fiscal year (* = New in 2008/09, ** completed in 2008/09):

*B.G. Rossnagel, G.J.Scoles & T.S. Grewal. FHB resistant oat for the FHB prone eastern Prairie region.. $150,000 over four years. WGRF, 2009 – 2011.

*B.G. Rossnagel, G.Scoles, S. Shirtliffe, C. McCartney. Oat R&D Agreement – Breeding, Grain Quality and Associated Molecular Genetics enhancement and expansion. $1,420,000 over three years. 2008/09 -2010/2011.

* B.G.Rossnagel. Barley Research & Development, $120,000/yr, SeCan Association, 2008/09 – 2017/18.

B.G. Rossnagel, T.S.Grewal, G.J.Scoles and C. McCartney. Resistance genes and molecular markers for spot blotch resistance combined with net blotch resistance for Saskatchewan barley. $190,000 over 3 yrs. Sask ADF, 2007/08 – 2009/2010.

* B.G. Rossnagel, S. Shirtliffe, G. Scoles, C. McCartney. Oat Breeding, germplasm development, pathology and agronomy. $100,000/yr., Saskatchewan Oat Development Commission, 2008/09 – 2013/14.

B.G. Rossnagel. 2-row Malting Barley R&D. $90,000/yr. Parrish & Heimbecker, 2007/08 – 2011/12.

B. G. Rossnagel, Joint malting barley R&D agreement, $70,000/year, Sapporo Breweries Japan and Prairie Malt Ltd., Biggar, SK. 2008/09 – 2010/11.

* A.M.Ferrie and B.G.Rossnagel. Double haploidy for Oat. $415,541 over 5 yrs. Sask ADF, 2007/08 – 2012/2013.

P. Leterme et al, including B.G.Rossnagel. Hulless barleys as functional feeds for swine. $50,000 over two yrs, Alberta Barley Commission, April 2006 - March 2008.

B.G.Rossnagel, FHB screening of CDC barley breeding selections, $65,000 per year, Sask ADF 2006/07 – 2010/11.

B.G. Rossnagel and G.J. Scoles, Eastern Prairie Barley Check-off CDC Project, WGRF, $300,000/yr., 2006 - 2014.

B.G. Rossnagel. R&D Agreement re joint oat variety development for New Zealand. Future royalties from commercial product sales. PlantRes NZ, ongoing since 2005.

B.G. Rossnagel. R&D Agreement re joint oat variety development for eastern Canada with PhytoGene Resources Inc., Orleans, ON. Future royalties from commercial product sales. PhytoGene Resources, 2006 – 2016.

W. Legge et al including B.G. Rossnagel, funding to enhance FHB screening capabilities at AAFC, Brandon, MB. $100,000/year. Canadian Wheat Board, 2005/06-2008/09.

W. Legge et al including B.G. Rossnagel, funding to enhance FHB screening capabilities at AAFC, Brandon, MB. $55,000/year. Manitoba ARDI, 2005/06-2008/09.

W. Legge et al including B.G. Rossnagel, funding to enhance FHB screening capabilities at AAFC, Brandon, MB. $45,000/year. Alberta ACIDF, 2005/06-2008/09.

R. Chibbar, M. Baga and B. Rossnagel. Study of starch granule size distribution to improve barley grain quality. $276,288 Sask ADF, 2006/07 – 2008/09.

J. McKinnon, B. Rossnagel et al. Optimizing opportunities for specialty oat varieties for feedlot rations. $77,752. Sask ADF, 2006/07 – 2007/08.

P. Yu and others including B. Rossnagel. Evaluation of nutritive values of different varieties of barley for ruminants comparisons. $88,850, Sask ADF, 2006/07 – 2008/09.

**B.G. Rossnagel, G.J.Scoles & T.S. Grewal. Resistance genes and markers for net blotch resistant barley for western Canada. $177,500 over four years. Sask ADF, 2004/05 – 2007/08.

C. McCartney, B.G. Rossnagel, G.J. Scoles and J. Chong. Characterization and deployment of novel oat crown rust resistance for Saskatchewan and western Canada. $438,825 over 5 yrs. Sask ADF, 2006/07 – 2010/11.

B.G. Rossnagel. 2-row Standard Quality Hulled Feed Barley Development, $60,000/yr, SeCan Association, 1999 - 2009.

B.G. Rossnagel. Commercially confidential Oat R&D agreement, $60,000/yr, Farm Pure Seeds, 2006/07 – 2010/11.

B. Coulman and B.G. Rossnagel. Development of forage oat and barley cultivars with improved nutritive value. $60,000/yr. Sask ADF, 2006/07 – 2008/09.

**B.G. Rossnagel, G.J. Scoles and S. Shirtliffe, Preferred Milling Oat Research and Development, $230,000/yr, Quaker Oats Co. Ltd., U.S.A. and Cargill Canada Ltd., 2004-2008.

B.G. Rossnagel. R&D Agreement re Specialty starch barley with InfraReady Products Ltd., Saskatoon. Future royalties from commercial product sales. 2004 – 2014.

**R. Chibbar, B. Rossnagel, M. Baga. Development of Molecular Markers for Beta Glucan Content of Barley. $221,600, Sask ADF, 2004-2007.

**A.Tekauz, J. Mitchell-Fetch, N. Ames, B. McCallum, B. Rossnagel. Identifying and incorporating resistance to FHB in Oat. $127,500 over 3 yrs. WGRF, 2004/05 – 2007/08.

**B.G. Rossnagel. CDC/Agricore Specialty Starch Hulless Barley Research Agreement. $50,000/yr., Agricore Ltd., 2004 – 2007/08.

B.G. Rossnagel, Joint malting barley R&D agreement, $70,036/year, Sapporo Breweries Japan and Prairie Malt Ltd., Biggar, SK. 2005/06 – 2007/08, extended to 2011.

**B.G. Rossnagel. SuperOat breeding and research agreement. $55,000/yr., Super Oats Canada Ltd., 2006/07 – 2007/08.

**B.G. Rossnagel. 2-row Malting Barley Development, $100,000/yr, SeCan Assoc., 2005 –08.

Outreach Activities B.G. Rossnagel, March 2008.- February 2009:
Continued as CDC rep to SSGA Board of Directors 2008/2009
Continued membership on FII (formerly PFRC) advisory board
Presentation to WGRF – 2008/9 CDC Barley R&D workplan – March 3, 2008
Webtalk presentation to CIGI malt barley course March 11, 2008
SARDI oat group visit July 10, 2008
Canterra Seeds field tour and mtg July 21, 2008
Quaker Oats mtg and field tour, July 22, 2008
Oat Industry Field day, July 23, 2008
SeCan field tour at Vanscoy, July 28, 2008
WGRF Barley Adv Comm presentation, July 30, 2008
WGRF Barley Adv Comm field tour, July 31, 2008
SeCan field tour, August 13, 2008
CWB Chinese delegation presentation and field tour, August 28, 2008
Sapporo/PML mtg, Sept 12, 2008
Richardsons mtg, Sept 16, 2008
Sapporo mtg and field tour, Sept 18, 2008
CMBTC Tech comm. Mtg, Oct 30, 2008
CSGA InterProvincial mtg, Nov 5 & 6, 2008, Banff
NFS mtgs Nov 12 & 13, 2008, Winnipeg
Quaker update mtg, Nov 20, 2008
SACGC annual mtg and report, Nov 27, 2008
POGA presentation, Dec 4, 2008, Yorkton
SMA agrologists update presentation, Dec 10, 2008
SSGA Seed Industry mtg, Jan 13, 2009
SODC presentation, Jan 13, 2009
SSGA CDC new varieties update, Jan 14, 2009
SK Beef Industry Symp presentation, Jan 21, 2009
Canadian rep on International Advisory Committee USDA Barley Genomics CAP project 2005 to date.
> 20 press and live media interviews
> 250 one-on-one producer, end-user and regulatory sector industry contacts

Public Property:

Refereed articles:
12. Papers in ref journals

Accepted:

Nicholas A Tinker, Andrzej Kilian, Charlene P Wight, Katarzyna Heller-Uszynska, Peter Wenzl, Howard W Rines, Ã.smund BjÃ¸rnstad, Catherine Howarth, Jean-Luc Jannink, Joseph M Anderson, Brian G Rossnagel, Deon D Stuthman, Mark E Sorrells, Eric W Jackson, Stine

Tuvesson, Frederic L Kolb, Olof Olsson, Luiz Carlos Federizzi, Marty L Carson, Herbert H Ohm, Stephen J Molnar, Graham J Scoles, Peter E Eckstein, J. Michael Bonman, Alf Ceplitis and Tim Langdon. 2009. New DArT markers for oat provide enhanced map coverage and global germplasm characterization. BMC Genomic, January, 2009.

Published:

B.G. Rossnagel, T. Zatorski, G. Arganosa and A.D.Beattie. 2008. Registration of CDC Lophy-I barley. Journal of Plant Registrations Vol 2, No 3, pp 1-5.

A. Tekauz, J.W.Mitchell-Fetch, B.G. Rossnagel and M.E.Savard. 2008. Progress in assessing the impact of FHB on oat in western Canada and screening of Avena germplasm for resistance. Cereal Res Comm Vol 36 Suppl 6 49-55.

B.G. Rossnagel, T. Zatorski, W.D.Voth, G.J.Scoles, W.G.Legge, J.R.Tucker, A.Tekauz and M.E.Savard. 2008. Registration of CDC Mindon barley. Journal of Plant Registrations Vol 2, No 2, pp 79-84.

K.J.Hart, B.G. Rossnagel and P.Yu. 2008. Chemical characteristics and in situ ruminal parameters of barely for cattle; Comparison of the malting cultivar AC Metcalfe and five feed cultivars. Can J Animal Sci. 88:711-719.

R. Pieper, R. Jha, B. Rossnagel, A.Van Kessel, W. Souffrant and P. Leterme. 2008. Effect of barely and oat cultivars with different carbohydrate compositions on the intestinal bacterial communities in weaned piglets. FEMS Microbial Ecol 66 (2008) 556-566.

T.S.Grewal, B.G. Rossnagel and G.J.Scoles, 2008. The utility of molecular markers for barley net blotch resistance across geographic regions. Crop Science. 48:2321-2333.

T.S.Grewal, B.G.Rossnagel, G. Bakkeren and G.J.Scoles, 2008. Identification of resistance genes to barley covered smut and mapping of the Ruh1 gene using Ustilago hordei strains with defined avirulence genes. Can J, Plant Path. 30: 277-284.

M.Salarmoini, G.L. Campbell, B.G.Rossnagel and V. Raboy. 2008. Nutrient retention and growth performance of chicks given low-phytate, conventional or hull-less barleys. British Poultry Sci. 49(3) 321-328.

J. Li, M. Baga, B.G. Rossnagel, W.G.Legge, R.N. Chibbar. 2008. Identification of quantitative trait loci for beta-glucan concentration in barley grain. J. Cereal Sci. 48 (2008) 647-655.

Peiqiang Yu, Brian G. Rossnagel, and Zhiyuan. Niu. 2008. Protein value of a new genotype oat (CDC SO-I) for the NRC dairy model: Protein degradation balance and kinetics, protein fractions and total metabolizable protein supply. Canadian Journal of Animal Science 88 (3) 501-513.

T. Grewal, B.G. Rossnagel, C.J.Pozniak and G.J. Scoles, 2008. Mapping quantitative trait loci associated with barley net blotch resistance. TAG 116:529-539.

Invited presentations:

Ten – IOC, Swedish Oat Assoc., WGRF, POGA, SODC, SSGA, CIGI, Quaker Oats x 2, WBDC
Co-author – one – PAG 2008

Conference presentations

Five - Lead or Co-author – NABRW (3), CPS SK & AB (1), EBC (1)

Conference posters:

Eleven – 8th IOC (4), 3rd Intl FHB symp (1), Plant & Animal Genome (1), NABRW (3), ASBC World Brew Congress(1), CSAS/ASAS (1).

Commercializable property

CDC Landis 2R malting barley registered June 2008. Seed production and distribution TBA.

CDC Meredith 2R malting barley registered May, 2008. Seed production and distribution to be handled by SeCan..

CDC Reserve, 2R malting barley registered May, 2008. Marketing rights awarded to SeCan..

CDC PolarStar, 2R malting barley registered May, 2008. Marketing rights awarded to Canterra Seeds.

HB390 two-row hulless barley, TR06389 two-row feed barley supported for registration February 2008. Seed production and marketing rights for both to SeCan. Registration to be completed in 2008.

Resources Required but not available

- administrative assistance for personnel and project budget management and reporting. With the amalgamation of the Plant Sciences Dept. 2 row malting barley R&D program into the existing CDC Barley and Oat program (essentially doubling the PY component of the program), the continued downloading of U of S administrative work to individual PIs, the ever increasing unrealistic and unnecessary expectation for greater accountability both within the U of S and from outside funding agencies including SDA&F, WGRF, industry funders and others, this issue is becoming more and more critical.
- resources for field and lab equipment maintenance, repair and replacement
- funding for proof of concept work with end users
- loss of technical staff and difficulty in recruitment and retention of replacements
- MUCH MUCH MORE TIME – operating three full scale breeding programs for the past 30 years was a lot to manage but the addition of the fourth – 2R malting barley – is really taxing the limits of one FT scientist.

Flax Beeding and Genetics

Principal Investigator – G. Rowland

Overall Objective

The creation of flax cultivars for Saskatchewan with improved agronomic, quality and market traits.

Sub-objectives

1. The development of Saskatchewan oilseed flax cultivars suitable for linseed markets.
2. The development of novel lines of flax suitable for the registering as cultivars for specialized industrial, food, nutraceutical or health markets.
3. The development of breeding methodologies for production of flax varieties with enhanced straw fibre concentration.
4. Obtaining and evaluation of novel flax germplasm for suitability for use in developing cultivars adapted to Saskatchewan.
5. Assist with technology transfer, research management, industry organizations and private enterprise for flax production and variety commercialization.

Outputs

Outputs for 2008-2009 include

One third year, one second year and ten first year lines were entered into the 2008 Flax Cooperative Test. The third year line FP2242 was supported by the Prairie Recommending Committee for Oilseeds (PRCO) for variety registration in Canada. The second year line FP2258 will be reentered into the third year of Coop testing. In 2 years of Coop testing FP2258 has yield equal to CDC Bethune but with improved oil content and quality. One first year line, FP2276 has been entered into the second year of the 2009 Flax Cooperative Test. FP2276 showed improvement in oil content and iodine value over the check variety CDC Bethune.

FP2242

The cross between CDC Bethune and FP2006 was made in the Phytotron at the University of Saskatchewan in 1998. The F_2 population was grown at the Kernen Farm in 1999 and advanced using the pedigree system from the F_3 through F_6. Selection at each generation was primarily for vigour of stand, maturity, oil concentration and iodine value. From 2003 through 2005 the line was evaluated as F03154 in replicated yield trials in Saskatchewan. It was entered into the Flax Cooperative Test in 2006 as FP2242 and tested through to 2008. FP2242 is similar in yield to CDC Bethune in western Canada and is higher yielding than CDC Bethune in Saskatchewan. It has a similar seed size to CDC Bethune and has acceptable quality traits. There were 135 long rows of FP2242 grown at the Kernen Farm with an excellent yield of 300 kg. Several of the long rows showing off types were removed and the remainder bulk harvested to form the Breeder Seed of the variety.

- Two Flax Cooperative tests were successfully grown at the Kernen Farm in 2008; the Early Seeded and Late Seeded tests.
- One set of short rows consisting of 150 lines of the 2nd year Coop entry FP2258 was grown and harvested at the Kernen Farm.
- Seven lines with superior performance were identified from 48 second year entries in the 2008 Tertiary Flax Test grown by the CDC Flax Program at three Saskatchewan locations. These lines (F06010, F06011, F06012, F06022, F06080, F06157, F06193) have been entered into the 2009 Flax Cooperative Test. In particular, F06010, F06011 and F06012 showed improved yield, oil content and iodine value over CDC Bethune.
- There were 61 first year entries in the 2008 Tertiary Flax Tests identified for a second year of Tertiary testing in 2009.
- The 48 lines from the 2nd year Tertiary entries, plus 5 CDC check varieties, were grown and harvested in Secondary Increases (56 rows of each). Also increased in a similar manner were 7 special fatty acid lines.
- One hundred and eighty-eight Preliminary Increases of 1st year Tertiary entries were grown (7 rows) and harvested at the Kernen Farm.
- There were 372 F_6 lines evaluated in 12 Preliminary Yield Tests conducted at the Kernen Farm and 183 of these have been identified for advancement into the 2009 Tertiary tests.
- There were 20 entries evaluated in two Special Fatty Acid Tertiary tests in 2008. One test was for brown seeded lines that had either high levels of linoleic (18:2) or linolenic (18:3) fatty acid and the other for yellow lines varying in the same fatty acids. Three of these lines (F06371, F07579 and F07040) have been identified for additional Tertiary testing in 2009 in order to identify possible contact registration candidates for testing in 2010.
- Thirteen Preliminary Increases of 1st year Special Oil Tertiary entries were grown (7 rows) and harvested at the Kernen Farm.
- There were 61 lines of varying fatty composition and seed colour evaluated in preliminary yield trials with the hope of identifying candidates for niche market opportunities. Some of the lines have high linolenic (omega-3) fatty acid content while others have high linoleic (omega-6) content. The best of these will be evaluated in the Special Fatty Acid Tertiary tests in 2009.
- Approximately 8900 $F_3 - F_6$ lines (rows) were seeded and evaluated at the Kernen Farm. Of this total 2900 were selected for further evaluation.
- There were twenty-two F_2 populations raised at the Kernen Farm in 2008 and 150 plants were selected from each of these. These selected plants will each become rows in the 2009 F_3 Nursery.
- The production of thirty-four F_1 crosses that produced seed to be used in growing the 2009 F_2 populations.
- The 2008 Flax SAC trial was grown and harvested at the Kernen Farm (Saskatoon).
- There were 352 entries from the Coop and Tertiary tests evaluated in the Flax Wilt Nursery located at the Preston Avenue plot area.
- One M.Sc. student supervised (Paula Chatfield).
- Two Ph.D. students (Sushmita Mitra and Natalie Coetzee) supervised.
- Three conference/workshop presentations.

- One conference poster paper.

Nandy, S. and Rowland, G. (July 2008). Dual-Purpose Flax (*Linum usitatissimum* L.) Improvement Using Anatomical and Molecular Approaches. International Conference on Flax and Other Bast Plants, Saskatoon.

Coetzee, N. and Rowland, G. (July, 2008). Selection for Straw Fibre in Oilseed Flax. International Conference on Flax and Other Bast Plants, Saskatoon.

Rowland, G. (August, 2008). The Effect of Plants with Novel Traits (PNT) Regulation on Mutation Breeding in Canada. FAO/IAEA International Symposium on Induced Mutations in Plants. Vienna, Austria.

Rowland, G. (December, 2008). An Update on TUFGEN (Total Utilization Flax Genomics). CFGI Flax Genomics: Platforms and Possibilities Workshop, Saskatoon.

Flax Research Projects

Off-season (Winter) Nursery for Flax
ADF Project #20070050
Gordon Rowland

Funding source: Agriculture Development Fund of Saskatchewan, the Saskatchewan Flax Development Commission and the Crop development Centre
Term: 2007-2012
Total Budget: $225,000

Flax yields in Saskatchewan have not been keeping pace with canola and it is felt that this will have a negative impact on the continued growth of the crop in Saskatchewan. In short, if we do not improve flax yields it will only be grown as a specialty crop on greatly reduced acres. This would be very unfortunate as flax acreage has grown from a yearly average of 500,000 acres in the 1980's to over 1.2 million acres presently. Average flax yields had grown during this period to the point where it surpassed average canola yields in Saskatchewan in the late 1990's. However, the breeding advances made recently in canola have left flax in the dust. Flax yields have fallen to 80% of that of canola. The seed yielding ability of flax must be raised and it must be done quickly or canola will get so far ahead that we will never catch up again. The establishment of a winter nursery for flax will help to speed the development of higher yielding varieties by allowing two generations to be grown in one year.

Recurrent selection has been shown to be a useful breeding stategy for improving seed yield. A modified form of recurrent selection is proposed for flax. Approximately 500 F4 plants from high yielding bulk populations grown at the Kernen Farm will be selected and threshed each year. The 500 F5 lines will then be grown in a winter nursery in New Zealand. Seed from harvested rows in the winter nursery will be returned to the CDC in late March. This seed will be used to grow preliminary yield trials at the Kernen Farm for the identification of superior yielding lines. The best of the lines will be further evaluated for possible variety release. They will also be inter-crossed to begin another breeding cycle.

Please see the annual report submitted to ADF for progress on the project.

Mining of CDC Bethune EST's for the Development of Seed Specific DNA Markers
ADF Project #20070024
Gordon Rowland, Gopalan Selvaraj and Raju Datla

Funding source: Agriculture Development Fund of Saskatchewan, the Plant Biotechnology Centre and the Crop Development Centre.
Term: 2007-2010
Total Budget: $503,700

The seed coat of flax is the site of accumulation of lignans, which offer numerous health benefits and it also produces mucilage, a mineral-rich "gum" of interest to the food industry. The lack of dark polyphenolics in the seed coat makes the seeds appear yellow and this is of interest with respect to identity preservation and marketing of alternate oil lines as well as for the animal feed industry.

One of the things that is holding back the development of flax in comparison to other crops is the paucity of genetic markers. In contrast to other crops such as canola and peanut , there is no compilation of microsatellite (simple sequence repeat; SSR) markers and their transferability to various varieties of flax. This even though SSR has emerged as a very useful and relatively simple-to-use marker.

The Plant Biotechnology Institute (PBI) has now generated 155,000 expressed sequence tags (ESTs) from messenger RNAs isolated from key stages of developing seed using CDC Bethune flax. This is the largest EST collection to date for this crop and an estimated 1 million dollar investment by the PBI. Of this collection, ~40,000 ESTs are from seed coat tissues. While this was in progress, the Flax Program at the CDC initiated the development of populations of recombinant inbred lines (RILs). RILs are a valuable genetic source for generating a map of DNA markers and for mapping genetic traits that differ in the original parental lines of the RILs. This proposal will exploit these two resources for generating a molecular map and for deriving genetic handles for seed coat traits in flax. We have established a cytological reference for seed development in flax and have determined the temporal aspects of lignan accumulation in flax seed coat tissue. The information and materials from these studies will be used in the current project.

Please see the annual report submitted to ADF for progress on the project.

Development of High Oleic Flax with Enhanced Oil Concentration
ADF Project #20070023
Gordon Rowland, Xiao Qiu and Martin Reaney

Funding source: Agriculture Development Fund of Saskatchewan, and the Crop Development Centre.
Term: 2007-2010
Total Budget: $386,100

Presently there are four basic oil types of flax that have been developed; traditional varieties with 60% linolenic acid in the oil, high linolenic varieties with approximately 70% linolenic acid, solin varieties with 70% linoleic acid and high linoleic types with approximately 80% linoleic acid. A call was made at the 2007 Plant Bio-Industrial Oils Workshop in Saskatoon for a high oleic flax oil that could act as a platform for the development of new specialty oil flax types. There is also the possibility of direct industrial use for such an oil if oleic levels can be raised to high enough levels. Greater seed oil levels in all the variations of flax oil would be a valuable trait making flax a more competitive crop for both edible and industrial purposes.

Single, half-seed analysis by gas-chromotography will be carried out on high oleic accessions from Plant Gene Resources of Canada to determine fatty acid composition and the highest oleic types selected. These plants will be raised in the Phytotron and crossed to a high linoleic solin line. Eventually high oleic/low linolenic F_3 plants will be selected and those from unrelated high oleic parents intercrossed with the hope that very high oleic types will arise from some of these crossing pairs.

Seed harvested from field grown, high seed oil F2 populations will be selected for increased oil concentration using density selection. Seed with a high seed oil concentration will be germinated and grown in the phytotron and lines producing >50% selected for further evaluation. The progeny from these plants will be evaluated in the field and compared to progeny selected for seed oil concentration in the traditional way from the same F2 populations. The high oil trait will then be introgressed back into the high oleic lines as well as other CDC flax breeding material.

Please see the annual report submitted to ADF for progress on the project.

Phenotyping of Recombinant Inbred Lines (RILs) Derived From CDC Bethune Crosses and Describing and Sampling of M2 Mutated Lines

ADF Project #20080028

Gordon Rowland and Dorothy Murrell

Funding source: Agriculture Development Fund of Saskatchewan, and the Crop Development Centre.
Term: 2009-2010
Total Budget: $125,000

The base genetic resources that are required for flax genomic studies are in place but they now need to be phenotyped (their key traits described/determined) in order to apply the genomic tools that will be developed from the Expressed Sequence Tags (EST) being produced at the PBI/NRC from CDC Bethune. Presently, finishing the recombinant inbred populations (RILs) involving 5 seed colour genes that also carry genes for fatty acid composition, oil content, seed size, flower colour and other important seed traits is nearing completion. In addition, CDC Bethune has been mutated with ethyl methane sulphonate (EMS) and the M1 generation raised at the Kernen Farm. The PBI/NRC has produced approximately 150,000 ESTs from seed tissue of CDC Bethune and will build another 250,000 in the near future. The phenotyping of 3000 F7 Recombinant Inbred Lines (RILs) of five crosses involving five lines with different seed colour genes and CDC Bethune, and the raising, describing and sampling of 15,000 M2 lines of EMS treated seed of

CDC Bethune will occur over the next two growing seasons. The phenotype information of each line will be utilized in genomic studies that will occur in the Genome Canada supported flax program TUFGEN (Total Utilization Flax Genomics) and other flax genomic initiatives. This information will be needed for the development of molecular markers for key flax traits and for both forward and reverse genetic studies on the crop. The outcome for the farmer and agri-industry of Saskatchewan will be new flax varieties which show incremental improvements in agronomic and quality factors for the commodity, value-added and niche markets for which flax is so well suited, with the potential for new value-added industry development around such flax characteristics as fibre and specialty oils.

Cereal and Flax Pathology

Principal Investigator: Curt McCartney

Overall Objective

The overall objective of the cereal and flax pathology program is to advance knowledge of the genetics of host-pathogen interactions and apply this information in the development of cereal and flax cultivars for Saskatchewan and western Canada.

Specific objectives

- To support breeding efforts to improve or maintain host resistance to the major diseases, improve resistance to the secondary diseases, and to identify resistance to potentially new diseases;
- To identify sources of resistance, study the inheritance of host resistance, identify markers for resistance genes, and transfer of resistance into elite germplasm;
- To assess virulence variability in pathogen populations, and monitor virulence over time to ensure the deployment of effective resistance genes;
- To investigate the economic importance of new diseases, study the epidemiology, investigate control measures, and develop protocols for germplasm screening;
- To study the biological basis of host-pathogen interactions with the goal of understanding plant pathogenesis at the molecular level and developing cultivars with disease resistance that is durable over time;
- To develop disease management strategies for pathogens of economic importance in Saskatchewan.

Plan to Achieve Objectives

1. Evaluation of disease resistance in breeding lines:
Field disease nurseries were established to evaluate the resistance of breeding lines, developed by the CDC wheat breeding programs, to leaf and stem rust, common bunt, and the leaf spot complex. The leaf and stem rust nursery was conducted on irrigated land and was inoculated with an epidemic mixture of leaf and stem rust isolates provided by Dr. Brent McCallum and Dr. Tom Fetch (AAFC – Winnipeg). Susceptible spreader rows were artificially inoculated, which generated the inoculum that ultimately infected the breeding lines. Over 10,000 wheat lines were evaluated for leaf and stem rust resistance in 2008. The common bunt nursery was inoculated with a mixture of *Tilletia tritici* races T-1, T-6, T-13, T-19 and *T. laevis* races L-1 and L-16 in an approximate ratio of 1:1:1:1:2:2. The seed of the test entries were coated with the spore mixture and seeded early in the season to promote bunt infection. Nearly 400 wheat lines were evaluated for common bunt resistance in 2008. The leaf spot nursery utilized natural inoculum and was located at the Goodale Research Farm, where leaf spots are endemic. Over 800 wheat lines were evaluated for leaf spot reaction in 2008. Reaction to loose smut was evaluated in greenhouse tests. Entries were artificially inoculated at anthesis with a mixture of *Ustilago tritici* races. Infected seed are planted in the greenhouse and the percentage of smutted plants was recorded. Three hundred and sixty-five wheat lines were evaluated for loose smut resistance in 2008. Good

selection differential was achieved in all of these tests. Screening for FHB resistance in field tests was coordinated between the CDC wheat breeders and Dr. Anita Brûlé-Babel (U of Manitoba).

The CDC Cereal and Flax Pathology program jointly evaluated flax wilt with the CDC Flax Breeding Program. Entries were evaluated in three replicate tests. The flax entries were seeded into infested soil and rated once for initial stand, and three times for wilt and plant vigor over the growing season. Selection differential was relatively poor to previous years. This was likely due to the dry spring and above average rainfall in late June and July, which did not place strong water stress on the plants.

2. Leaf spot resistance in wheat:

The main objectives of this research project are to identify information that will improve the efficiency of breeding leaf spot resistance in spring and durum wheat, and implementing this information in wheat breeding populations developed for improving leaf spot resistance. Significant progress was made on this project in 2008. Virulence variation in *Stagonospora nodorum* was characterized on a differential set of 16 wheat lines. The data indicated the presence of a number of races in Saskatchewan and Manitoba. Eleven single spore cultures of *S. tritici* were isolated in 2008 from the 2007 field season. Additional cultures are currently being isolated from the 2008 field season. As part of the breeding for leaf spot resistance project, fourteen single crosses were made in the spring of 2008 and ten three-way crosses were made in the fall of 2008. Finally, the Kenyon/86ISMN 2137 and Altar Synthetic/Kenyon mapping populations were characterized for reaction to the *S. nodorum* isolate Kelvington. Numerous DNA markers were collected on these populations for linkage and QTL analyses.

Seedlings inoculations were conducted in the controlled environment studies. Inoculations were done at the two leaf stage and plants were incubated in a humidity chamber to ensure successful infection. Plants were rated using appropriate rating scales once disease symptoms were fully developed. Pathogen isolates were obtained from diseased wheat leaves from Saskatchewan and Manitoba.

3. Crown rust resistance in oat:

Funding was secured from Quaker Tropicana Gatorade (QTG) and the Saskatchewan Oat Development Commission (SODC) in 2008. This funding established an oat crown rust nursery at the CDC in 2008 and will provide operating funding for the nursery into the future. This new funding is greatly appreciated and will enhance existing research on the genetics of crown rust resistance.

From the research perspective, excellent progress was made on this project in 2008. A number of crosses were made to study new crown rust resistance sources. Twelve crosses were made between AC Morgan and *Avena sterilis* lines with crown rust resistance at the CDC in 2008. F_1 seed of nine crosses made at AAFC-Winnipeg were provided by Dr. James Chong. The seedling crown rust resistance gene *Pc91* was mapped relative Diversity Array Technology (DArT) markers. Seven of the DArT markers were converted to PCR-based, Sequence-Characterized Amplified Region (SCAR) markers, which are suitable for marker-assisted selection of *Pc91*. Six new genetic populations are under development for adult plant crown rust resistance.

Seedlings inoculations were conducted in the controlled environment studies. Inoculations were done at the one or two leaf stage and plants were incubated in a humidity chamber to ensure successful infection. Plants were rated using appropriate rating scales 12 to 14 days after inoculation.

4. Septoria leaf mottle in canaryseed:
Protocols to evaluate canaryseed reaction to *Septoria triseti* were developed. *S. triseti* was compared to wheat leaf spotting pathogens grown on artificial media. Growth of *S. triseti* and *S. tritici* cultures could not be distinguished on artificial media. Experiments evaluated the suitability of *S. tritici* inoculation protocols for *S. triseti*. Development of symptoms were also compared between the two pathogens on both canaryseed and wheat. Each pathogen was specific to host and symptoms in a similar fashion and timeframe. The *S. tritici* protocols were appropriate for *S. triseti*.

Seedlings inoculations were conducted in the controlled environment studies. Inoculations were done at the two leaf stage and plants were incubated in a humidity chamber to ensure successful infection. Plants were rated using a *S. tritici* rating scale at 17 and 21 days after inoculation.

5. Common bunt in winter wheat:
The CDC Cereal & Flax Pathology program is participating in collaborative experiment to study the ability of common bunt to infect winter wheat at different sites in western Canada (Lethbridge, Saskatoon, and Winnipeg). This project was initiated by Dr. Denis Gaudet (AAFC-Lethbridge) in the fall of 2007. The objective of the test will test the hypothesis that common bunt is less severe on the eastern Prairies (black soil zone). This hypothesis has arisen because the black soils of the eastern Prairies may be warmer in the fall thus reducing common bunt incidence. Cool soil temperature, at the time of wheat emergence, is known to promote common bunt infection. This project will help clarify the desirable disease resistance packages for winter wheat in different regions of the prairies.

This test consists of inoculated and non-inoculated rows of three winter wheat lines that vary in susceptibility to common bunt. Each location has three seeding dates, each of which consists of five replicates.

Expected Outcomes

The expected outcomes of the cereal and flax pathology program are the development and release of improved cereal and flax cultivars possessing resistance to important diseases of these crops in western Canada and the development of disease management strategies for cereal and flax producers in western Canada.

Outputs

Graduate Student Supervision

Erin Matlock – M.Sc. student. Genetic analyses in the *Triticum-Stagonospora nodorum* pathosystem. Started in January 2008. (Supervisor)

Sally Vail – Ph.D. student. Genetic studies on resistance to anthracnose in lentil. (Committee Member)

Aurélie Cohen-Skali – Ph.D. student. Genetic study of the two races of *Collectotrichum truncatum* on lentil. (Committee Member)

Jennifer Menat – Ph.D. student. Studies on the mating system of *Collectotrichum truncatum* (Teleomorph: *Glomerella truncata*). (Committee Member)

Tamira Delgerjav – M.Sc. student. Genetic improvement of kabuli chickpea for ascochyta blight resistance and double podding by molecular approaches. (Committee Member)

Undergraduate Student Supervision

Ryan Goodwin. Inheritance of *Septoria tritici* resistance in the cross Kenyon/86ISMN 1237. Agric 492.3 (2008-2009)

Steven Leibel. Identification of *Septoria triseti* resistance in canaryseed accessions and breeding lines. Agric 492.3 (2008-2009)

Brittany Chovin. The threat and movement of the stem rust strain Ug99 on worldwide wheat production. Agric 492.3 (2008-2009)

Greg Tomcala. Factors affecting the severity of ergot. Agric 492.3 (2008-2009)

Derek Berg. Comparative studies between *Septoria triseti* and the leaf spotting pathogens of wheat. Agric 492.3 (2007-2008)

Teaching

PLSC 335.3 Integrated Pest Management.

Peer Reviewed Publications

B. Fofana, D.G. Humphreys*, S. Cloutier, C.A. McCartney, and D.J. Somers, 2008. Mapping Quantitative Trait Loci Controlling Common Bunt Resistance in a Doubled Haploid Population Derived from the Spring Wheat Cross RL4452 x AC Domain. Mol. Breed. 21: 317-325.

Non-Peer Reviewed Publications

J. Chong, J. Gruenke, R. Dueck, C.A. McCartney, and W. Mayert. 2008. Crown Rust of Oat in the Eastern Prairie Region of Canada in 2007. Can. Plant Dis. Surv. 88: 71-72.

Scientific Presentations

C. McCartney, G. Hughes, P. Singh, P. Hucl, and C. Pozniak. 2008. Resistance to the Leaf Spotting Complex in the Wheat Line 86ISMN 2137. Joint annual meeting of PPSA and CPS-SK, Lloydminster, AB, 20-22 October 2008.

E. Matlock, C. McCartney, G. Hughes and P. Singh. 2008. Genetics of *Stagonospora nodorum* blotch resistance in the wheat population Altar Synthetic/Kenyon. Joint annual meeting of PPSA and CPS-SK, Lloydminster, AB, 20-22 October 2008.

W. Cao, G. Fedak, D. Somers, C.A. McCartney, A. Xue, M.E. Savard, H. Voldeng, 2008. Effectiveness of Marker Assisted Selection for Resistance to Fusarium Head Blight in a Wheat Backcross Breeding Program. 11th International Wheat Genetics Symposium, Brisbane, Australia, 24-29 August 2008.

Extension Presentations

F. Dokken, M. Fernandez, C. McCartney, B. Rossnagel, and T. Grewal. 2008. Cereal crop disease summary - 2008. Saskatchewan Plant Disease Committee, 8 December 2008, Saskatoon, SK.

Funding

B. Rossnagel, G. Scoles, C.A. McCartney, and S. Shirtliffe, Oat Breeding, Germplasm Development, Pathology and Agronomy, $500,000, Saskatchewan Oat Development Commission, 1 July 2008 – 30 June 2013, $100,000, $33,000 to CAM.

R. Holm, and C.A. McCartney, Efficacy of Evito on Wheat Diseases caused by Fungi, $2,400. Arysta LifeScience Corporation, 1 May 2008 – 31 August 2008, $2,400, $1,000 to CAM.

P. Hucl, C.A. McCartney, and R. Chibbar, Canaryseed Hybridization Protocol, Disease Resistance and DNA Marker Development, $492,800, Saskatchewan Agriculture Development Fund, 1 April 2008 – 31 March 2013, $98,560, $10,000 to CAM.

B. Rossnagel, T. Grewal, G. Scoles, and C.A. McCartney. Resistance Genes and Molecular Markers for Spot Blotch Resistance Combined with Net Blotch Resistance for Saskatchewan Barley, $190,000, Saskatchewan Agriculture Development Fund, 1 March 2008 – 31 October 2010, $63,333, $0 to CAM.

B. Rossnagel, G. Scoles, S. Shirtliffe, and C.A. McCartney, Oat Research and Development Agreement, $1,420,000, Quaker Tropicana Gatorade (QTG) Canada Inc., 1 January 2008 – 31 December 2010, $473,333, $47,333 to CAM.

C.A. McCartney, New Faculty Award, $15,000, University of Saskatchewan College of Graduate Studies and Research, 11 March 2008 – 10 March 2010, $7,500.

C.A. McCartney, VP Academic Additional Capital Equipment Start-Up Research Funds, $18,000, University of Saskatchewan, 17 January 2008 – 2 October 2009, $9,000.

C.A. McCartney, College of Agriculture and Bioresources Start-Up Funds, $25,000, College of Agriculture and Bioresources, University of Saskatchewan, 7 June 2007 – 6 June 2009, $12,500.

C.A. McCartney, Genetic Characterization of the *Triticum-Stagonospora nodorum* Pathosystem, $131,105, Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant, 1 April 2007 – 31 March 2012, $26,221.

C.A. McCartney, P. Hucl, C. Pozniak, A. Brûlé-Babel, and J. Gilbert, Combining Effective Resistance Genes to the Saskatchewan Leaf Spotting Complex in Spring and Durum Wheat, $170,500, Saskatchewan Agriculture Development Fund, 1 April 2007 – 31 March 2011, $42,625, $42,625 to CAM.

C.A. McCartney, B. Rossnagel, G. Scoles, J. Chong, and T. Zatorski, Characterization and Deployment of Novel Oat Crown Rust Resistance for Saskatchewan, $288,825, Saskatchewan Agriculture Development Fund, 1 April 2007 – 31 March 2012, $57,765, $57,765 to CAM.

P. Hucl, C. Pozniak, C.A. McCartney, and D. Somers, Enhancing Fusarium Head Blight Resistance in Spring and Durum Wheat using Novel Approaches, $260,567, Saskatchewan Agriculture Development Fund, 1 April 2007 – 31 March 2010, $86,856, $0 to CAM.

C.A. McCartney, VP Academic Operating and Capital Equipment Start-Up Research Funds, $17,000, University of Saskatchewan, 3 October 2006 – 2 October 2008, $8,500.

P. Hucl, B. Fowler, C. Pozniak, and G. Hughes (C.A. McCartney assumed G. Hughes portion of grant), Wheat Breeding for Western Canada, $5,850,000, Western Grains Research Foundation Wheat and Barley Check-off Fund, 1 April 2005 – 31 March 2015, $585,000, $69,000 to CAM.

G. Hughes (C.A. McCartney assumed G. Hughes portion of grant), P. Hucl, and C. Pozniak, Disease Resistance Screening for Spring Wheat Breeding Programs at the University of Saskatchewan, $246,900, Saskatchewan Agriculture Development Fund, 1 April 2004 – 31 March 2010, $41,150, $41,150 to CAM.

Collaborators
Anita Brûlé-Babel
Ravi Chibbar
James Chong
Pete Eckstein
Myriam Fernandez
Tom Fetch
Brian Fowler
Jeannie Gilbert
Pierre Hucl
Brent McCallum
Curtis Pozniak
Brian Rossnagel
Gordon Rowland
Graham Scoles
Pawan Singh
Daryl Somers
Tom Zatorski

Field Pea Breeding

Principal Investigator: Tom Warkentin

Overall Objective

Development of early maturing, high yielding field pea cultivars with resistance to powdery mildew and improved resistance to mycosphaerella blight and lodging with acceptable quality for export and domestic food and feed markets.

Sub-objectives

1. Food and feed pea breeding
2. Specialty pea breeding

Plan to Achieve Objectives

1. Food and feed pea breeding

Crossing, F1, and F2 generations

Approximately 300 new populations were generated in 2008 during the course of three crossing cycles (summer, fall and winter) with the objective of producing food or feed cultivars. When possible, gamete selection was used to screen pollen donors for single gene traits. The F2-derived family method was used. Visual selection for seed quality traits was conducted in each generation; these include size, shape, dimpling, cotyledon and seed coat colour, and seed coat integrity. Selection for powdery mildew resistance was conducted in the F1 generation of complex crosses, or the F2 generation of single crosses.

F3 generation

Approximately 15,000 F2-derived F3 lines were evaluated in single replicate micro-plots in 2008 at the SPG farm near Saskatoon. Approximately 2300 of these will be advanced to F4 preliminary yield trials in 2008 with one replicate at each of two locations (one full set at the Sutherland nursery near Saskatoon, and the other replication divided between Rosthern and Meath Park nurseries), based on selection for plant type, lodging resistance, maturity, and mycosphaerella blight resistance.

F4 generation

Approximately 2300 F4 lines were evaluated in preliminary yield trials in 2008. One replicate was evaluated at the Sutherland nursery near Saskatoon. The second replicate was evaluated at either Rosthern or Meath Park. Lines with early maturity pedigrees were tested at the short season site (Meath Park). Approximately 19% of the 2008 preliminary lines (F4) were chosen for 2009 advanced (F5) trials based on yield, lodging resistance, maturity, and seed quality.

F5 generation

Approximately 300 F5 advanced lines were evaluated in two replicate yield trials at 5 locations (Saskatoon, Rosthern, Wilkie, Rouleau and Meath Park) in 2008. The 96 most promising of these will be tested in F6 Elite tests at 8 locations in 2009. Promising yellow cotyledon lines generally had yield 2-12% above the mean of the yellow checks, with lodging scores usually as good as the best check. Promising green cotyledon lines generally had yield 5-15% above the mean of the green checks with lodging scores usually as good as the best check, and bleaching resistance similar to the best check.

F6 generation

A total of 96 F6 or F7 elite lines were evaluated in two replicate yield trials at 8-9 locations in 2008. These sites included those at which F5 trials were conducted plus Outlook, Elrose, and Morden or Lacombe. Twelve promising lines were identified for evaluation in the 2009 Field Pea Co-operative Test (Co-op Test). Promising yellow cotyledon lines had yield 5-15% above the mean of the yellow checks with lodging score similar to the best check, and with medium or medium-early maturity. Promising green cotyledon lines had yield 5-10% above the mean of the green checks with lodging score similar to the best check, medium or medium-early maturity, and bleaching resistance similar to the best check.

Co-op Test

Five CDC lines were evaluated in the second (final) year of the Co-op Test in 2008. Three of these were recommended for registration: two yellow cotyledon lines (CDC1897-14 and CDC1897-3) and one green cotyledon lines (CDC1932-201) at the February 2009 PGDC meetings. Ten lines were evaluated in the first year of the 2008 Co-op Test; nine of these will be advanced to second year testing in 2009.

Regional Trial

Fourteen CDC varieties were evaluated in the Saskatchewan pea regional trial in 2008. Cultivar Cutlass was the yield check in 2008 and had strong yield performance. Top yielders included CDC varieties CDC Treasure, CDC 1749-8, CDC Patrick, CDC 1759-30, and CDC 1734-5, AAFC varieties Agassiz, Thunderbird, Canstar and Reward, and Limagrain varieties Sorento, Polstead, and Cooper.

Recent variety releases

Yellow cotyledon variety CDC Meadow (CDC 653-8) was released by Saskatchewan Pulse Growers in 2006. CDC Meadow has powdery mildew resistance, good lodging resistance, relatively early maturity, medium seed size and good yield potential.

Yellow cotyledon variety CDC Centennial (CDC 728-8) was released by Saskatchewan Pulse Growers in 2007. CDC Centennial has powdery mildew resistance, fair lodging resistance, relatively early maturity, medium-large seed size and good yield potential.

Green cotyledon variety CDC Patrick (CDC 1434-20) was released by Saskatchewan Pulse Growers in 2008. CDC Patrick has powdery mildew resistance, good lodging resistance, medium maturity, medium-small seed size, good resistance to cotyledon bleaching and good yield potential.

Yellow cotyledon variety CDC Prosper (CDC 1400-8) was released by Saskatchewan Pulse Growers in 2008. CDC Prosper has powdery mildew resistance, good lodging resistance, medium maturity, small seed size (155 mg) and good yield potential. The small seed size will reduce planting costs, but may require segregation in marketing.

New breeder seed releases in 2009
Yellow cotyledon variety CDC Treasure (CDC 1410-15) was released by Saskatchewan Pulse Growers in spring 2009. CDC Treasure has powdery mildew resistance, good lodging resistance, early maturity, medium seed size and good yield potential.

Methodology
Standard 4-row yield plots with rows 4 m long and 30 cm apart were used at most locations. Pre-breeder seed development was initiated concurrent with Elite testing. Single plants were selected from the best performing Elite lines. These were grown as microplots concurrent with first year Co-operative Testing, and as long plots concurrent with second year Co-operative Testing. Breeder seed of new varieties is typically bulked after long plot evaluation.

Cultivars arising from this process are typically suitable for both food and feed markets. In recent years, lines in F5 and later generations have been tested using Near Infrared Spectroscopy to predict proximate analysis.

2. Specialty pea breeding

Specialty market classes currently under consideration include maple, dun, forage, and marrowfat. Approximately 70 new populations were generated in 2008 with the objective of producing specialty pea cultivars. A similar methodology as described above for food and feed pea breeding was used.

Yellow cotyledon forage variety CDC Leroy (CDC 1287-2) was released by Saskatchewan Pulse Growers in 2008. CDC Leroy has powdery mildew resistance, good lodging resistance, medium maturity, small seed size, good grain yield potential and good biomass productivity.

Expected outcomes

Pulse crops are currently grown on approximately 14% of the annual planted area of Saskatchewan. Using a typical one in four rotation, the potential exists for a doubling of pulse crop area of production in the province. Expanded area of production is contingent on many factors, one of which is improved pulse crop cultivars.

Expected outcomes of the CDC field pea breeding program include increased economic returns to producers and the pulse crop marketing industry due to the following factors.

- higher yield
- lower input costs due to improved disease resistance and improved lodging resistance
- improved food and/or feed quality
- access to new specialty pea markets with improved cultivars

Outputs

Outputs for 2007-2008 include the following.

- Five second year and ten first year lines entered in the 2008 Field Pea Co-op Test.
- Seven varieties (CDC1767-23, CDC1812-5, CDC1759-6, CDC1759-30, CDC1749-8, CDC1734-5, CDC1659-13) recommended for registration in February 2008.
- Breeder seed of one yellow cotyledon variety (CDC Prosper), one green cotyledon variety (CDC Patrick) and one forage pea variety (CDC Leroy) was released for the first time in 2008.
- Student supervision

Ph.D. student Aziz Rehman defended his thesis on the topic of genetic and physiological aspects of drought tolerance in chickpea. He is currently conducting post-doctoral research in our group on low phytate pea.

Ph.D. student Lasantha Ubayasena in progress on the topic of genetic control of key seed quality traits in pea.

M.Sc. student Tamira Delgerjav in progress on the topic of physiological effects of the low phytate trait in pea.

- Six scientific manuscripts published in 2008-2009.

Gan, Y., Zentner, R., McDonald, C., Warkentin, T.D., and Vandenberg, A. (2009) Adaptability of chickpea in northern high latitude areas - maturity responses. Agricultural and Forest Meteorology 149:711-720.

Chandirasekaran, R., Warkentin, T.D., Gan, Y., Shirtliffe, S., Gossen, B., Tar'an, B. and Banniza, S., (2009) Improved sources of resistance to ascochyta blight in chickpea. Can. J. Plant Sci. 89:107-118.

H.J. Chung, Q. Liu, E. Donner, R. Hoover, T.D. Warkentin, and A. Vandenberg, 2008. Composition, molecular structure, thermal properties, pasting characteristics and *in vitro* digestibility of starches from newly released Canadian cultivars of pea, lentil and chickpea. Cereal Chem. 85:471-479.

H.J. Chung, Q. Liu, R. Hoover, T.D. Warkentin, and A. Vandenberg, 2008. *In vitro* starch digestibility, expected glycemic index and thermal and pasting properties of flours from pea, lentil and chickpea cultivars. Food Chem. 111:316-321.

L. Li, R.A. Bueckert, Y. Gan, and T.D. Warkentin, 2008. Light Interception and Radiation Use Efficiency of Fern- and Unifoliate-Leaf Chickpea Cultivars. Can. J. Plant Sci 88:1025-1034.

A. Tullu, B. Tar'an, T.D. Warkentin, and A. Vandenberg, 2008. Construction of an Intraspecific Linkage Map and QTL Analysis for Earliness and Plant Height in Lentil (Lens culinaris Medikus). Crop Sci. 48:2254-2264.

- Thirty conference presentations authored or co-authored in 2008-2009.

Smýkal, P., Bochard, A.M., Warkentin, T.D., Mikić, A., Ellis, N., Golstein, C., and Schneider, A. (2009) GL-TTP: a technology transfer platform for grain, forage and other legume communities. European Grassland Federation (Brno, Czech Republic).

Azarnia, S., Boye, J. I. Boye, Warkentin, T.D., Malcolmson, L., Sabik, H., Bellido, A.S. (2009) Optimization of headspace solid-phase microextraction gas chromatography for the characterization of volatile compounds in peas. Institute of Food Technologists annual meeting (Anaheim, CA).

Smýkal P., Ellis T. H. N., Bochard A. M., Warkentin T.D., Mikić A. and Schneider A. (2009) GL-TTP: a technology transfer platform for grain, forage and other legume communities. European Grassland Federation conference (Brno, Czech Republic).

Garrett, R.G., Gawalko, E., Warkentin, T.D., Wang, N. and Richter, A. (2009) Macro-relationships between regional-scale field pea (*Pisum sativum*) chemistry and soil-type and eco-classification in western Canada. Canadian Society of Soil Science (Guelph).

Tar'an, B., Ife, S., Barlow, B., Sapsford, K., Banniza, S., Warkentin, T., Holm, F.A. (2009) Effects of herbicide applications on ascochyta blight disease in chickpea. Pulse Days 2009, Saskatchewan Pulse Growers, Saskatoon.

Diederichsen, A., Lulsdorf, M., Banniza, S., Tar'an, B., and Warkentin, T. (2009) Two wild relatives of the cultivated chickpea as potential sources of resistance to ascochyta blight. Pulse Days 2009, Saskatchewan Pulse Growers, Saskatoon.

Grewal, R., Lulsdorf, M., Croser, J., Ochatt, S., Warkentin, T., and Vandenberg, A. (2009) World's first doubled haploid plants in chickpea and field pea: a research success story. Pulse Days 2009, Saskatchewan Pulse Growers, Saskatoon.

Gurusamy, V., Bett, K., Warkentin, T., and Vandenberg, A. (2009) Asexual propagation techniques to accelerate breeding efficiency in major legume crops. Pulse Days 2009, Saskatchewan Pulse Growers, Saskatoon.

Gurusamy, V., Banniza, S., Tar'an, B., and Warkentin, T. (2009) Breeding outside the box: possibility of using wild pea (*Pisum fulvum*) for ascochyta blight resistance in field pea breeding. Pulse Days 2009, Saskatchewan Pulse Growers, Saskatoon.

Rehman, A., Warkentin, T., Malhotra, R.S., Bett, K., and Bueckert, R. (2009) Molecular mapping of drought tolerance in kabuli chickpea. Pulse Days 2009, Saskatchewan Pulse Growers, Saskatoon.

Ubayasena, L., Warkentin, T., Bett, K., Tar'an, B., Vijayan, P., and Bing, D. (2009) Identification of genomic regions controlling key visual quality traits affecting the market value of field pea. Pulse Days 2009, Saskatchewan Pulse Growers, Saskatoon.

Azarnia, S., Boye, J., Warkentin, T., Malcolmson, L., Sabik, H., and Bellido, A. (2009) Identification of flavour compounds in selected yellow peas grown in Saskatchewan. Pulse Days 2009, Saskatchewan Pulse Growers, Saskatoon.

Ebsim, S., Warkentin, T., and Classen, H. (2009) In vitro starch digestibility as affected by cultivar and grind size. Pulse Days 2009, Saskatchewan Pulse Growers, Saskatoon.

Thavarajah, D., Ruskowski, J., Warkentin, T., Tar'an, B., Bueckert, R., Bett, K., and Vandenberg, A. (2009) Biofortification of pulse crops. Pulse Days 2009, Saskatchewan Pulse Growers, Saskatoon.

Thavarajah, D., Warkentin, T., Tar'an, B., Bueckert, R., Pozniak, C., Hucl, P., and Vandenberg, A. (2008) Breeding for nitrogen fixation in cereal-legume cropping systems. 7th Canadian Pulse Research Workshop. Winnipeg.

Grewal, R., Lulsdorf, M., Croser, J., Ochatt, S., Vandenberg, A., and Warkentin, T. (2008) Double haploid production in chickpea and field pea. 7th Canadian Pulse Research Workshop. Winnipeg.

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Rehman, A., Warkentin, T., Malhotra, R.S., Bett, K., and Bueckert, R. (2008) Characterization and molecular mapping of drought tolerance in chickpea. 7th Canadian Pulse Research Workshop. Winnipeg.

Tullu, A., Fiala, J., Tar'an, B., Warkentin, T., Bett, K., and Vandenberg, A. (2008) Using genes from wild species to reduce pesticide use in pulse crops. 7th Canadian Pulse Research Workshop. Winnipeg.

Ubayasena, L., Warkentin, T., Bett, K., Tar'an, B., Vijayan, P., and Bing, D. (2008) Identification of genomic regions controlling key visual quality traits affecting the market value of field pea. 7th Canadian Pulse Research Workshop. Winnipeg.

Valarmathi, G., Bett, K., Warkentin, T., and Vandenberg, A. (2008) Grafting as a tool in breeding of large-seeded pulse crops (bean, pea and fababean). 7th Canadian Pulse Research Workshop. Winnipeg.

Marles, S., Holm, R., and Warkentin, T. (2008) Allelopathic attributes of field pea. 7th Canadian Pulse Research Workshop. Winnipeg.

Wang, N., Toews, R., Hatcher, D., Warkentin, T., Maximiuk, L., and Shaluk, D. (2008) Physico-chemical and cooking characteristics of field pea as affected by genotype and environment. 7th Canadian Pulse Research Workshop. Winnipeg.

Stoughton-Ens, M., Hatcher, D., Wang, N., and Warkentin, T. (2008) Influence of genotype and environment on dietary fibre content of field pea grown in Canada. 7th Canadian Pulse Research Workshop. Winnipeg.

Thavarajah, D., Ruskowski, J., Warkentin, T., Tar'an, B., Bueckert, R., Bett, K., and Vandenberg, A. (2008) Biofortification of pulse crops. 7th Canadian Pulse Research Workshop. Winnipeg.

Tar'an, B., Holm, F., Banniza, S., Sapsford, K., Warkentin, T., Vandenberg, A., Ife, S., and Barlow, B. (2008) Effects of herbicide applications on ascochyta blight disease in chickpea. 7th Canadian Pulse Research Workshop. Winnipeg.

Smýkal, P., Mikic, A., Warkentin, T., Bochard, A.M., Schneider, A., and Ellis, N. (2008) GL-TTP: a technology transfer platform for grain legume community. IV International Conference on Legume Genomics and Genetics (Puerto Vallarta, Mexico).

Mikić, A., Warkentin, T., Mihailović, V., Krstić, D., and Vojin S. (2008) Agronomic characteristics of Canadian and Serbian varieties of dry pea (*Pisum sativum* L.). Breeding 08 conference, Novi Sad, Serbia.

Warkentin, T., Vandenberg, A., Tar'an, B., Banniza, S. and Bett, K. (2008) Field pea genetic improvement at the University of Saskatchewan. Breeding 08 conference, Novi Sad, Serbia.

Ubayasena, L., Warkentin, T., Bett, K., Tar'an, B., and Bing, D. (2008) Genetic analysis, QTL mapping and gene expression analysis of key visual quality traits affecting the market value of field pea. Grain Legume Technology Transfer Platform Workshop, Novi Sad, Serbia.

- Eleven extension presentations in 2008-2009.
- Cargill crop extension meeting on February 10, 2009 at Battleford, SK on the topic "Pulse breeding and research program".
- SPG/SAF Pulse Extension Meeting on February 5, 2009 at Weyburn, SK on the topic "Pulse breeding and research program".
- SPG/SAF Pulse Extension Meeting on February 4, 2009 at Moose Jaw, SK on the topic "Pulse breeding and research program".

- SPG/SAF Pulse Extension Meeting on February 3, 2009 at Swift Current, SK on the topic “Pulse breeding and research program”.
- Select Seed Growers meeting presented by the Saskatchewan Pulse Growers at Saskatoon, SK on January 14, 2009, on the topic “Potential new field pea varieties”.
- Processors and Growers Research Organization at Peterborough, England on December 5, 2008 on the topic “Pulse crop breeding at the University of Saskatchewan”.
- Pulse Crop Genetic Improvement Network at the John Innes Centre in Norwich, England on December 2, 2008 on the topic “Pulse crop breeding at the University of Saskatchewan”.
- INRA in Dijon, France on October 16, 2008 on the topic "Pulse crop genetic improvement at the University of Saskatchewan".
- General assembly of the Grain Legumes Technology Transfer Platform workshop on November 25, 2008 at Novi Sad, Serbia on the topic “Pulse crop production in Canada and USA”.
- Grain legume genetics group at the John Innes Centre on October 14, 2008 at Norwich, England on the topic “"Pulse crop genetic improvement at the University of Saskatchewan".
- British Edible Pulse Association annual meeting at Peterborough, England on November 6, 2008 on the topic “Pulse breeding – a Canadian perspective”.

Pulse Crop Research Projects

Improving the value of field peas for human consumption markets

Tom Warkentin, Bunyamin Tar'an, Kirstin Bett, Dengjin Bing and Lasantha Ubayasena
Funding source: SPG-ADF
Term: 2005-2008
Total Budget: $300,000

Summary

Visual quality is one of the major factors determining the market value of field pea (*Pisum sativum* L.). Breeding for improved visual quality of pea seeds is currently a challenging task, mainly because of the complexity and the lack of sound genetic knowledge of the traits. The objectives of this research were to characterize the genetic basis and conduct QTL mapping of four key quality traits (cotyledon bleaching in green pea, greenness in yellow pea, seed shape, and seed dimpling in both green and yellow types). Gene expression profiling to understand the molecular basis of post-harvest cotyledon bleaching in green pea was addressed in this project. Two $F_{5\ 6\ \mathrm{recombinant}}$ inbred line (RIL) populations (93 lines from Orb X CDC Striker cross, and 120 lines from Alfetta X CDC Bronco cross) were developed and evaluated for the quality traits in two locations in Saskatchewan, Canada in 2006 and 2007. The four quality traits evaluated all displayed a continuous range of expression among the relevant RILs, with moderate to high heritability. Two genetic linkage maps utilizing 201 markers (30 SSR (from Agrogene) and 171 AFLP markers) and 155 markers (21 SSR and 134 AFLP markers) were constructed for Orb X CDC Striker and Alfetta X CDC Bronco populations, respectively. Three major QTLs on linkage group (LG) IV and one QTL on LG V for green cotyledon bleaching resistance were identified. Three QTLs on LG I and IV using Orb X CDC Striker population and one major QTL on LG VII with two additional QTLs on LG VII and I using the Alfetta X CDC Bronco population

associated with seed shape were recognized. Three QTLs on LG I and IV associated with seed dimpling were recognized using the Orb X CDC Striker population, while no significant QTLs were detected on the linkage map of Alfetta X CDC Bronco population for this trait. Two major QTLs associated with greenness in yellow pea seeds on LG I and II were recognized. The bleaching resistant cultivar CDC Striker had a slower rate of chlorophyll degradation in cotyledons, and a higher carotenoid to chlorophyll ratio in seed coats, than the bleaching susceptible cultivar Orb when seed samples were exposed to high intensity light. An oligonucleotide microarray (Ps6kOLI1) was utilized to study the gene expression patterns to understand the molecular mechanism of bleaching resistance in pea seed coats. The gene expression profiles of the CDC Striker and Orb seed coats were significantly different during the seed developmental stages at 14 and 21 days after flowering (DAF). A significant up-regulation of genes involved in the production and accumulation of secondary metabolites which are responsible for antioxidant properties in plants tissues such as kaempferol 3-0 glucoside, quercetin 3-0 glucosides, pentunidin 3-0 glucoside, and malvidin 3-0 glucosides, in the seed coats of CDC Striker at 14 and 21 DAF were observed.

On-Farm Pulse Crop Germplasm Evaluation

Tom Warkentin, Bert Vandenberg and Bunyamin Tar'an
Funding source: SPG-ADF
Term: 2004-2009
Total budget: $581,000

Summary

The rapid expansion of the pulse industry including diversification into many market classes has resulted in expansion of breeding programs. This has led to problems of land management at research station screening sites and the need for evaluation of breeding lines in target environments. We overcame these problems by designing a flexible, low unit cost breeding system based on on-farm screening in key environments. Obvious deficiencies in the CDC pulse breeding testing program in the early part of this decade were detected as follows: dry bean in SE Saskatchewan, lentil and pea in the Regina plain and the acid soil region of west-central Saskatchewan, and pea in the short-season Parkland region. This five-year project, which began in the 2004 season, addressed these deficiencies using an on-farm pulse crop germplasm testing approach. This report summarizes the research activities in 2008. The activities in the 2004-2007 seasons were summarized in previous annual reports. Pulse crop breeding lines were arranged into standard yield trials. F4-F7 generation lines were evaluated in 2008 trials. Only one or two crops were evaluated per location to increase the efficiency of trial maintenance. At each location, nurseries were established in pulse growers' fields of the corresponding crop. Planting date closely coincided with the growers' planting date. Nurseries were arranged in a manner that allowed the grower to apply herbicides and fungicides to pulse plot areas using large-scale equipment, thus reducing the number of visits to the sites by the CDC pulse crop breeding crew, and therefore, reducing the per plot cost. Nurseries were conducted at the following locations in 2008, with the following growers: dry bean at Oxbow (Wayne Amos), field pea at Meath Park (Kevin Skragg), lentil and field pea at Pasqua (Harvey Marcil), lentil and field pea at Wilkie (Adam Davey). A total of 7839 plots were evaluated in 2008 at a cost of approximately $10 per plot. The Pasqua site was substituted for the Rouleau site in 2008. The Pasqua site provided a similar soil type and saved one hour of travel time per round trip. In general, growing conditions resulted in above average yields of pea and lentil with average grain quality. Rainfall conditions were above average resulting in good growing conditions. Trials at all four locations provided valuable data for selecting superior lines for 2009 trials.

Pulse crop regional variety trials
Tom Warkentin, Bert Vandenberg, and Bunyamin Tar'an
Funding source: SPG
Term: 2006-2010
Total budget: $500,000

In 2006, the Saskatchewan Pulse Growers and the Crop Development Centre signed a 5-year Memorandum of Understanding for implementation of the Saskatchewan lentil, field pea, chickpea and dry bean regional trials. The CDC pulse breeding program co-ordinated the trials. Useful data were collected from most trials in 2008 allowing for timely reporting and decision-making.

Evaluation of field pea varieties for forage potential
Tom Warkentin, Eric Klassen, Bruce Brolley, and Jeff Kostiuk
Funding source: SPG
Term: ongoing
Total budget: $5,000 per annum

Summary

In response to industry demand, a trial was established for the fifth consecutive year in 2008 to evaluate pea varieties for forage/silage potential. Sites were grown on a voluntary basis by co-operators. A protocol was developed in consultation with interested co-operators in western Canada. The protocol involved growing field pea plots in pure stands, in plots of 4-6 rows, with row length of 4-5 m, using typical agronomic practices for field pea yield trials in the area. When the lower pods on the stems of the cultivar CDC Sonata had thickened, a 1 m^2 sample was cut at the soil level from the front of each plot for biomass assessments. The remainder of the plot was harvested for grain yield. Crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), and relative feed value (RFV) of biomass was assessed by Central Testing laboratory in Winnipeg. Eighteen entries from two breeding programs were assessed in 2008. Six of the test entries had dry matter production greater than the current check variety 40-10. Only one of the test entries equaled 40-10 in percent crude protein, however, all entries had lower percent ADF and NDF than 40-10, and all had greater RFV than 40-10. All test entries had greater seed weight than Trapper and 40-10, however, 10 had seed weight not more than 40 g/1000 seeds greater than 40-10. All of the test entries had greater grain yield compared to Trapper, CDC Sonata and 40-10. All of the semileafless varieties had lower lodging scores than 40-10. Based on the above criteria, several of the pea varieties in this trial have good potential to replace 40-10 as forage/silage pea varieties in western Canada.

Unlocking the bioavailability of phosphorus and micronutrients through development of low phytate pea
Tom Warkentin, Kirstin Bett and Hank Classen
Funding source: SPG and NSERC-CRD

Term: 2008-2013
Total Budget: $500,000

About 60-80% of the total phosphorus in crop seeds is stored in the form of an organic molecule called phytate. Phytate is generally not digested by humans and non-ruminant livestock; instead most is excreted along with the phosphorus bound to it, leading to the pollution of surface waters. Important micronutrients (such as K^+, Mg^{++}, Ca^{++}, Mn^{++}, Zn^{++}, Ba^{++}, and Fe^{+++}) bound to phytate are also excreted, potentially leading to micronutrient deficiencies in humans and livestock. Due to the nutritional and environmental concerns, development of cultivars with low phytate trait has become an attractive breeding objective in many crop species including maize, barley, soybean and rice. Two low phytate pea lines (1-2347 and 1-150) were recently isolated at the Crop Development Centre (CDC), University of Saskatchewan. This project is aimed at characterization of these lines at the physiological, genetic, biochemical and molecular level to understand the nature of the trait and set the stage for development of low phytate cultivars. Low phytate pea cultivars are expected to have improved bioavailability of phosphorus and several important micronutrients including iron and zinc, which increases their value in both food and feed markets. Secondly, when low phytate cultivars are fed to monogastric animals and humans, less phosphorus excretion and pollution will occur, since these cultivars contain inorganic phosphorus which is digested by these species. Thirdly, low phytate pea cultivars will result in a saving in feed costs, since the requirement for supplemental inorganic phosphorus or phytase enzyme will be reduced or eliminated.

Development of EST and SNP genomic resources to be employed in variety development of flax, lentil, chickpea and field pea
Wilf Keller, Dorothy Murrell Faouzi Bekkaoui, Kirstin Bett, Raju Datla, Gordon Rowland, Gopalan Selvaraj, Andrew Sharpe, Bunyamin Tar'an, Albert Vandenberg, and Tom Warkentin
Funding source: ADF
Term: 2008-2009
Total Budget: $400,000

The objective of this research is the development of foundational genomic resources, specifically Expressed Sequences Tags (ESTs) and Single Nucleotide Polymorphisms (SNPs) for application in flax, lentil chickpea and pea variety development.

Analysis of allele diversity for improvement of nutritional profile and disease resistance in pea
Tom Warkentin, Bunyamin Tar'an and Axel Diederichsen
Funding source: ADF
Term: 2008-2011
Total Budget: $210,000

The objectives of the project are as follows. Using pea accessions recently obtained from eastern Europe and Russia, 1) to identify allele variations for candidate genes related to carbohydrate metabolism, protein deposition or resistance to ascochyta blight; 2) to relate these variations with their phenotypic variations; and 3) develop SNP markers as tools for assisted breeding to incorporate the diverse alleles into new pea cultivars adapted to Saskatchewan.

Characterization of the flavour properties of selected pea varieties grown in Saskatchewan

Joyce Boye, Linda Malcolmson, and Tom Warkentin
Funding source: SPG
Term: 2008-2010
Total Budget: $181,000

The objectives of the proposed study are to: a) Characterise the flavour profiles of selected pea varieties grown in Saskatchewan, i.e., green, yellow, and marrowfat; b) Determine the impact of effect of primary processing (whole and split) and secondary processing techniques (infrared heat treatment and microwaving) on flavour development and stability; c) Study the interactions between pea components (proteins and starches) and determine the impact of these interactions on the flavour of pea flours when treated under different conditions; d) Determine the impact of storage conditions (time, temperature, humidity) on the flavour profile of pea seeds and flours. Sensory analysis using a trained panel and solid-phase microextraction-gas chromatography are the two main techniques to be used.

Perennial chickpea: potential for improving Ascochyta rabiei resistance

M. Lulsdorf, T. Warkentin, B. Tar'an, A. Diederichsen, and S. Banniza

Funding source: ADF and SPG
Term: 2005-2009
Total budget: $600,000

The project objective was to find sources with superior resistance to ascochyta blight in wild perennial *Cicer* species and to transfer this resistance into the cultivated chickpea. In field and greenhouse trials, accessions *C. anatolicum* PI 383626 and *C. oxyodon* PI 561103 were identified as having superior ascochyta blight resistance even under high disease pressure. Microscopic examinations showed that hybrids produced between the cultivated chickpea and these accessions aborted at the globular embryo stage. Future research will attempt interspecific hybridization via improvements to the pod rescue medium and via using *C. macracanthum* and *C. microphyllum* as bridge species.

Developing doubled-haploid technology for chickpea

R. Grewal, M. Lulsdorf, T. Warkentin, and B. Tar'an
Funding source: ADF
Term: 2006-2009
Total budget: $385,000

The objective of this project was to develop doubled-haploid technology for chickpea via anther and/or microspore culture. For the first time, haploid and double-haploid embryos and plants were produced through anther culture. Embryo formation occurred within 20 days of culture initiation through a combination of stress treatments. Flow cytometric analysis of callus, embryos and regenerated plants showed haploid profiles and/or spontaneous doubling of chromosomes during early regeneration stages. Three cultivars were used for the development of a microspore culture protocol by our Australian collaborator As a result globular embryos were obtained using cold treatment of buds in combination with ChM-10 medium.

Chickpea and lentil cultivar development for Alberta – Phase 2
B. Tar'an, A. Vandenberg, M. Bandara, T. Warkentin
Funding source: AARI
Term: 2006-2010
Total budget: $700,000

Southern Alberta has a great potential to produce high quality chickpea and lentil crops given high yielding adapted cultivars with market acceptance are available. This project serves as "Phase 2" of chickpea and lentil cultivar development for Alberta. In Phase 1, several advanced lines of lentil and chickpea were identified in this project with good potential for variety release. In addition, many other promising lines were identified in earlier generation trials. The objectives of this research project were: (1) to develop chickpea cultivars with desirable market traits in both kabuli and desi market classes and with early maturity, improved ascochyta blight resistance, and improved drought tolerance for production in the Brown and Dark Brown soil zones of Alberta; (2) to develop lentil cultivars with desirable market traits and with early maturity, improved ascochyta blight and anthracnose resistance, and improved drought tolerance for production in the Brown and Dark Brown soil zones of Alberta. Five kabuli, four desi and several lentil lines have been identified from this research which have potential for variety release within the next three years.

Pyramiding novel genes for resistance to ascochyta blight from *Pisum fulvum* into field pea through molecular breeding
Tom Warkentin, Valarmathi Gurusamy, Bunyamin Tar'an, and Sabine Banniza
Funding source: SPG
Term: 2008-2012
Total budget: $350,000

Ascochyta blight can substantially reduce field pea yields in western Canada. The principle cause of ascochyta blight is *Mycosphaerella pinodes*, although *Ascochyta pisi* and *A. pinodella* can also be involved. Several studies by various researchers indicate that, complete or high level resistance for ascochyta is not available in accessions of *Pisum sativum*, the cultivated species. Recent studies by Fondevilla *et al*., (2005) demonstrated that a few accessions of *Pisum fulvum*, a wild relative of field pea, possess a high level of resistance to ascochyta blight. The prospect of pyramiding genes, once identified from various sources with the aid of modern molecular techniques, will be the most fruitful approach for further improving resistance to ascochyta blight. This project is designed to initiate a long-term strategy for the enhancement and maintenance of resistance in pea for ascochyta blight using an integrated genetic improvement approach through interspecific hybridization, tissue culture techniques to accelerate hybrid development, plant pathology, and molecular genetics. Our approach will have three major components as follows: (1) identifying new resistance genes to ascochyta in selected *P. fulvum* accessions, (2) pyramiding those genes into adapted pea cultivars for developing ascochyta resistant germplasm, and (3) tagging the ascochyta resistance genes in peas.

Strategies for Future Funding

Potential future funding for field pea breeding include:

- Saskatchewan Pulse Growers pulse crop breeding grant: was renewed in 2005
- Saskatchewan Pulse Growers Pea Genetic Improvement Program: provides funding based on market share
- Alberta Pulse Growers Commission: five year funding recently renewed

Potential future funding for field pea research projects include:

- Saskatchewan Pulse Growers project funding
- Agriculture Development Fund project funding
- NSERC CRD program
- Alberta Agricultural Research Institute Genome Canada

Chickpea Breeding and Genetics

Principal Investigator: Bunyamin Tar'an

Overall Objectives

Development of high yielding, early maturing kabuli and desi chickpea cultivars with resistance to ascochyta blight and acceptable quality for each market class.

Plan to Achieve Objectives

Methodology

Each year three crossing cycles (summer, fall and winter) were done to create F_1 hybrids. Fall and winter crosses were done indoor at phytotron while the summer crossing was done in the polyhouse. The resulting F_1 seeds were grown in greenhouse during the winter and spring seasons and field nursery during the summer. F_2 plants were grown as micro plots or long plots if sufficient seeds were obtained. Standard 3 row-4 m long yield plots and 30 cm apart were used at two-five locations for the evaluation of F_4 (preliminary), F_5 (advanced) and F_6 (elite) tests. For the regional test, 4 row plots with the same length and row spacing were used for the evaluation of F_7 or higher generation at 8-10 locations each year. In each location a randomized complete block design or a lattice design was used to arrange the trials.

Pre-breeder seed development was initiated concurrent with the Elite (F_6) testing. Single plants were selected from the best performing Elite lines. These were grown as microplots, then as long plots in the following two seasons. Breeder seed of new varieties is typically bulked after long plot evaluation.

The 2008 cropping season in Saskatchewan in general was conducive for chickpea that resulted in above average yield. The good trial management have delivered useful data for the program.

Crosses and F_1 generation

A total of 479 new crosses were done in 2008 during the course of three crossing cycles (summer, fall and winter). The majority of these crosses involved at least one parent with large seed size, improved ascochyta resistance, earlier maturity or other specific characters. The resulting F_1 seeds were grown either in the greenhouse during the wintertime or in the polyhouse and field nursery during the summer.

F_2 generation

A total of 497 F_2 populations were grown as microplots (237 populations) and long plots (260 populations) at our breeding nursery at Kyle, SK. Single plant selection was done for each of F_2 populations based on overall plant characters, resistance to ascochyta blight and earliness. Each of these plants will become an F_3 micro plot in the 2009 growing season. These F_2 populations included remnant of 12 populations that were specially generated from the project funded by ADF (project # 20020160) and SPG (project # BRE0304) entitled "Strategy for Genetic Improvement of Ascochyta Blight Resistance in Chickpea (*Cicer arietinum*)"

F_3 generation

A total of 5,170 F_2-derived F_3 lines were evaluated in single replicate micro plots in 2008 at the breeding nursery at Kyle, SK. These lines were derived from 339 populations. Visual selection was done for each of the micro plots based on plant stature, ascochyta blight resistance, earliness, seed size, shape, seed coat colour (mostly for desi), and seed coat integrity.

F_4 generation

A total of 1,458 F_4 lines divided into 18 tests were evaluated in preliminary yield trials in 2008. One replicate was evaluated at the breeding nursery at Kyle and the second replicate was evaluated either at SPG Farm near Saskatoon or Pasqua, SK. Approximately 20% of the 2008 preliminary lines (F_4) were selected for 2009 advanced (F_5) trials based on yield, early maturity, ascochyta blight resistance and overall seed quality.

F_5 generation

216 F_5 (advanced) lines were evaluated in two replicate yield trials at 6 locations (Saskatoon, Brooks (AB), Davidson, Elrose, Kyle, and Pasqua) in 2008. Promising lines were identified with one or more of the following features: yield greater than the check (Amit for kabuli and Myles for desi), maturity earlier than CDC Frontier, ascochyta blight resistance similar to or better than CDC Frontier with seed size of 9 mm or bigger for the kabuli type and in the range of 200 – 300 g per 1000 seeds for the desi type. The most promising lines from these trials will be tested in F_6 Elite tests at 6-7 locations in 2009.

F_6 generation

A total of 60 F_6 elite lines (36 kabuli and 24 desi) were evaluated in two replicate yield trials at six locations in 2008. These sites included those locations in SK (Saskatoon, Elrose, Kyle, Davidson, and Pasqua) plus two locations in Alberta (Brooks and Bow Island) in collaboration with Dr. Manjula Bandara of Alberta Agriculture Brooks Station. Promising kabuli lines were identified with one or more of the following features: yield up to 12% greater than the check (Amit), maturity up to one week earlier than CDC Frontier, ascochyta blight resistance similar to CDC Frontier and a range of seed size. The most promising lines will be included in the kabuli regional trial at 10 locations in 2009.

The same locations (5 in SK and 2 in AB) were also used to evaluate 24 F_6 elite desi lines. The most promising lines that had yield potential of up to 29 % higher than the check (Myles) with acceptable maturity, seed quality and ascochyta blight resistance were selected and will be included in the 2009 desi chickpea regional trials at 10 locations.

F_7 and higher generations (Regional Trial)

Twenty-four entries were evaluated in the Saskatchewan kabuli (12 entries) and desi (12 entries) chickpea regional trials across ten locations (8 in SK and 2 in AB) in 2008. Six of the sites are located in Brown Soil zone and 4 in Dark Brown Soil zone. Useful data were obtained from 8 locations. Entries for each of kabuli and desi tests consisted of three check varieties and nine CDC breeding lines.

In the Brown Soil Zone (Area 1) in 2008, all kabuli entries had mean yield greater than the check (Amit) in the range of 102 to 116 %, whereas in the Dark Brown Soil Zone (Area 2), the average yield ranged from 86 to 105% of the check. The number of days to maturity ranged from 106 to 111 days. All the new entries had seed size in the range of 8 – 10 mm diameter (341 – 460 g/1000 seeds). Starting in 2008, one set of regional entries was seeded at the disease nursery near Saskatoon equipped irrigation facility that allows better conditions for ascochyta blight infection. Four entries in the kabuli test had ascochyta blight score comparable with CDC Frontier.

In 2008, all the entries in the desi regional tests had average yield higher than the check (Myles) in both Brown and Dark Brown Soil Zones. The yield ranged from 106 to 125 % of the check in the Brown Soil Zone and from 109 to 140 % of the check in the Dark Brown Soil Zones. All the entry, except 316B-42, had ascochyta blight score lower than the check.

Prebreeder Seed Development

In 2008, the prebreeder seed development included: bulk increased of one kabuli line (FLIP98-135C) and two desi lines (316B-42 and 512-51), long plots of three kabuli (493-24, 491-5 and 561as-18) and two desi entries (553-1 and 381T-4) and micro plots of 7 kabuli and 4 desi entries. The bulk increases were subcontracted with select growers located in southern SK. All other pre breeder seed increase (long plots and micro plots) were done at Kyle breeding nursery.

Observation/International Tests

A total of 699 lines at various generations were tested in 2008 at our breeding nursery at Kyle as micro plots with one or two replications with a series of local checks. These lines were provided by the International Chickpea Breeding Centres at ICARDA and ICRISAT. These materials were selected for specific traits such as drought tolerance, cold tolerance, resistance to fusarium wilt and ascochyta blight, leaf miner and other traits. The observation/international tests also included several breeding lines from the germplasm exchange programs with USDA/ARS, Australia and Ukrainian.

The summary of all chickpea trials conducted in 2008 is presented in Table 1.

Table 1. List of 2008 chickpea trials across different generations in the breeding program

Generation	Test Name	Total Test	Location	Design	Size (entry)/Test	Rows/Plot
F_4	Preliminary Yield Trials	18	2	9x9 Lattice	81x1	3
F_5	Advanced Yield Trials	6	6	6x6 Lattice	36x2	3
F_6	Elite Yield Trial - Desi	1	6	RCBD	24x2	3
F_6	Elite Yield Trial - Kabuli	1	6	6x6 Lattice	36x2	3
F_7 or higher	Regional Trial - Desi	1	10	RCBD	12x3	4
F_7 or higher	Regional Trial - Kabuli	1	10	RCBD	12x3	4
Various	International Nurseries	1	1	Various	699x1	3
Various	Germplasm Exchange - USDA	1	1	na	10x1	3
Various	Germplasm Exchange - Australia	1	1	na	12x1	3
F12	Chickpea Herbicide Test	1	2	Split plot	6x5x3	4

Outputs from 2008

New variety released in 2008

CDC Corinne (tested as ICC12512-1), a desi chickpea cultivar, was released in 2008 for distribution to Select seed growers in western Canada through the Variety Release Program of the Saskatchewan Pulse Growers. CDC Corinne has a pinnate leaf type, fair resistance to ascochyta blight, medium maturity, medium seed size and high yield potential in the Brown and Dark Brown soil zones.

Other outputs included the following:

- Bulk increase of three kabuli lines (491-5, 493-24 and CP71) for potential release in 2010
- Bulk increase of four desi lines (512-51, 553-1, CP55 and CP73) for potential release in 2010/2011
- A number of fourth, third, second and first year entries for the 2009 kabuli and desi chickpea regional trials
- 33 F_6 lines will enter 2009 elite kabuli test
- 21 F_6 lines will enter 2009 elite desi test
- Senior authored or co-authored of 11 presentations at the provincial, national and international meetings/conferences in 2008.
- Three new research projects as principal investigator or co-PI.
- Senior author or co-author of 9 scientific publications including variety descriptions in international refereed journals,
- Member of advisory committee of one Ph.D. student and one master student
- Supervisor of undergraduate thesis research projects
- Chickpea crop coordinator for the Saskatchewan Advisory Council on Grain Crops
- Member of Ascochyta blight response team
- Member of several departmental committees

Current Research Projects

Molecular Genetic Resources for Accelerated Breeding of Lentil Germplasm Targeting New Market Opportunities.
Bett, K., P. Vijayan, B. Tar'an, T. Warkentin, A. Vandenberg, G. Selvaraj, A. Sharpe, and R. Datla.
Duration: 2008-2010
Funding source: Agricultural Bioproducts Innovation Program (ABIP) – Agriculture Agri Food Canada.
Amount awarded: $564,960

Development of EST and SNP Genomic Resources to be Employed in Variety Development of Flax, Lentil, Chickpea and Field Pea.
Keller, W., D. Murrell, F. Bekkaoui, K. Bett, R. Datla, G. Rowland, G. Selvaraj, A. Sharpe, B. Tar'an, A. Vandenberg and T. Warkentin.
Duration: 2008-2009
Funding source: Saskatchewan Ministry of Agriculture
Amount awarded: $ 400,000

Discovering the Relationship between Fungicides, Microbial Diversity, and Performance of Crops after Chickpea.
Gan, Y., C. Hamel and B. Tar'an.
Duration: 2008-2010
Funding source: Saskatchewan Pulse Growers and Agriculture and Agri Food Canada
Amount awarded: $207,600

Breeding for Enhanced Nitrogen Fixation in Cereal-Legume Cropping Systems in Saskatchewan.
Vandenberg, A., D. Thavarajah , T. Warkentin , B. Tar'an , R. Bueckert P. Hucl, C. Pozniak.
Duration: 2007-2010.
Funding source: Saskatchewan Pulse Growers and Natural Sciences and Engineering Research Council of Canada (NSERC)
Amount awarded: $500,000

Unlocking the Bioavailability of Phosphorus and Micronutrients through Development of Low Phytate-Phosphorus Pea.
Warkentin , T., Y.A. Kabeta, K. Bett, G. Arganosa, B. Tar'an and H. Classen.
Duration: 2007-2010.
Funding source: Saskatchewan Pulse Growers and Natural Sciences and Engineering Research Council of Canada (NSERC)
Amount awarded: $500,000

Reducing Production Risks of Chickpeas by Optimizing Fungicide Applications.
Banniza, S., Y. Gan, B. Tar'an.
Duration: 2008-2010.
Funding source: Saskatchewan Pulse Growers and Saskatchewan Ministry of Agriculture
Amount awarded: $293,200

Interaction of Herbicide Applications and Reaction to Ascochyta Blight in Chickpea.
Taran, B., R. Holm, S. Banniza.
Duration: 2008-2010.
Funding source: Saskatchewan Pulse Growers
Amount awarded: $180,000

Pyramiding Novel Genes for Resistance to Ascochyta Blight and Powdery Mildew from *Pisum fulvum* into Field Pea through Molecular Breeding.
Warkentin, T., G. Valarmathy, B Taran and S.Banniza.
Duration: 2008-2010.
Funding source: Saskatchewan Pulse Growers and Saskatchewan Ministry of Agriculture
Amount awarded: $380,000

Breeding for Enhanced Nitrogen Fixation in Cereal-Legume Cropping Systems in Saskatchewan.
A. Vandenberg (PI), D. Thavarajah , T. Warkentin , B. Tar'an , R. Bueckert P. Hucl, C. Pozniak

Term: 2007-2009
Funding source: SPG
Total budget: $ 250,000

Molecular Approaches for Fast Track Genetic Improvement of Kabuli Chickpea for Western Canada
Bunyamin Tar'an, Tom Warkentin, Bert Vandenberg and Kirstin Bett
Funding source: Saskatchewan Ministry of Agriculture
Term: 2007-2009
Total budget: $ 215,925

Off-Season Evaluation of Chickpea Breeding Lines (Phase II)
Bunyamin Tar'an, Tom Warkentin, Albert Vandenberg, Sabine Banniza and Rajendra Malhotra
Funding source: Saskatchewan Ministry of Agriculture
Term: 2007-2009
Total budget: $ 78,480

Decision Support Tools for Management of Ascochyta Blight on Chickpeas.
Goodwin, M., P. Pearse, S. Banniza, Y. Gan, B. Taran.
Duration: 2007-2009.
Funding Source: Agriculture and Agri Food Canada (Pesticide Risk Reduction Strategy & Initiative)
Amount awarded: $144,000.

Pulse Crop Regional Variety Trials
Tom Warkentin, Bert Vandenberg, and Bunyamin Tar'an
Funding source: Saskatchewan Pulse Growers
Term: 2006-2010
Total budget: $500,000

Chickpea and Lentil Cultivar Development for Alberta.
Tom Warkentin, Bert Vandenberg, Bunyamin Tar'an and Manjula Bandara
Funding source: AARI
Term: 2006-2011
Total budget: $711,500

Perennial Chickpea: Potential for Improving *Ascochyta rabiei* Resistance.
Tom Warkentin, Monika Lulsdorf, Bunyamin Tar'an, Axel Diederichsen, Sabine Banniza, and Nalini Mallikarjuna
Funding source: Saskatchewan Pulse Growers and Saskatchewan Ministry of Agriculture
Term: 2005-2008
Total budget: $600,000

Improving the Value of Field Peas for Human Consumption Markets.
Warkentin, T.D., K. Bett , B. Tar'an, and D.J. Bing
Duration: 2005-2008

Funding sources: Saskatchewan Pulse Growers and Saskatchewan Ministry of Agriculture
Amount awarded: $ 326,000

Strategies for Future Funding

Potential future funding for chickpea breeding include:
- Saskatchewan Pulse Growers pulse crop breeding grant
- Alberta Pulse Growers Commission: five year funding recently renewed

Potential future funding for chickpea research projects include:
- Saskatchewan Pulse Growers project funding
- Agriculture Development Fund project funding
- NSERC
- Alberta Agricultural Research Institute

Expected outcomes

Pulse crops are currently grown on approximately 12% of the annual planted area of Saskatchewan. Using a typical one in four rotation, the potential exists for increasing pulse crop area of production in the province. Expanded area of production is contingent on many factors, one of which is improved chickpea cultivars.

Expected outcomes of the CDC chickpea breeding program include increased economic returns to producers and the pulse crop processing/marketing industry due to the following factors:

- Release of new cultivars with higher yield and improved quality,
- Lower input costs due to improved ascochyta blight resistance and better disease management strategy (in collaboration with pulse pathology program),
- Reduced risk due to release of earlier maturing cultivars,
- Release of larger seed size kabuli cultivars with improved ascochyta blight resistance and earlier maturity,
- Release of high yielding desi cultivars with acceptable seed quality, improved ascochyta blight resistance and earlier maturity.

Dry Bean Breeding and Genetics

Co-investigators: Kirstin Bett and Bert Vandenberg

Overall Objective

Genetic improvement of adaptation, yield, seed coat characteristics, seed shape, agronomic characters such as pod clearance, cold tolerance and resistance to specific diseases such as seed borne bacterial blights, white mold and anthracnose.

The dry bean breeding program is conducted jointly with Dr. Kirstin Bett of the Department of Plant Sciences, who continues to assume greater responsibility for the entire bean breeding program. As directed in an overall agreement with Saskatchewan Pulse Growers, dry bean breeding is designated as a medium priority activity. Commercial partners are collaborators in the breeding program for specific market classes.

Sub-objectives

1. Standard market classes such as pinto, great northern, red, black and navy.
2. Specialty market classes such as flor de mayo, flor de junio, peruano (yellow) and carioca.

Results 2008-2009

New Variety Releases

We continued to develop high quality slow-darkening pinto bean and yellow bean breeding lines for Saskatchewan as part of a commercialization agreement with SPG and Walker Seeds Ltd. One pinto bean line and one yellow bean breeding line were multiplied in Mexico in the 2008-09 winter season. The pinto bean line as well as another pinto bean line were recommended for registration at the latest PRCPSC meeting in February 2009.

Early maturing black bean varieties from the program have been tendered to Walker Seeds Ltd.

Outputs

Outputs for 2008-2009 included the following.

- Seventeen breeding lines entered in the 2008 short and long season narrow row dry bean registration trials.
- Continued successful developments in commercialization of Canada's first slow-darkening pinto bean variety in collaboration with industry partners.
- Two slow-darkening pinto bean lines recommended for registration in February 2009.
- Breeder seed production of the second slow-darkening pinto and the first yellow bean variety and a common blight tolerant slow-darkening pinto bean variety in winter 2008-09.

- Contributed and invited conference presentations and posters were authored or co-authored, primarily at the 1st International Bean Congress (Celaya Mexico, June 2008), Plant Metabolism Conference (Banff, August 2008), 7th Canadian Pulse Research Workshop in Winnipeg (November, 2008), and Pulse Days 2009 (Saskatoon, January 2009) See www.pulse.usask.ca and www.saskpulse.com for details
- Several extension presentations (oral and posters) see www.pulse.usask.ca for details
- Ongoing upgrading of research extension website
- Hosted a meeting of Canadian public bean breeders in Saskatoon in August 2009 to try to coordinate trials and explore joint research opportunities.
- Two scientific manuscripts related to dry bean were published from June 2008- March 2009.

Expected Outcomes of Dry Bean Breeding Program

Dry bean is currently a minor component of the pulse industry, but the crop has growth potential, particularly in the eastern part of the province and under irrigation, based on cost of production, access to processing capacity and other fundamental economic factors. Expanded area of production is contingent on many factors. At this stage of economic development of the crop, the availability of marketable, high yielding varieties with early maturity is a major limitation.

Expected outcomes of the CDC dry bean breeding program include increased economic returns to producers and the pulse crop marketing industry due to the following factors.

- Higher yield through earlier maturity and improved growth habit
- Lower input costs due to improved disease resistance
- Reduced risk due to release of earlier maturing cultivars
- Release of higher value cultivars with desired market characteristics such as improved colour retention in the pinto and black classes, and improved seed appearance in all classes
- Release of high quality adapted specialty cultivars to facilitate market development efforts in specific markets.

Activities to Achieve Objectives

1. Standard market classes

More than 200 new dry bean crosses were made in the winter and summer cycles. The winter (2009) crossing cycle is underway. Molecular marker assisted selection is in use as means of identifying F1 hybrids with common bacterial blight resistance for use in an accelerated backcrossing scheme as well as in regular crosses. The F2-derived family method is the general system of breeding. The summer field season is used to generate F2 populations by selecting among any F1 plants derived from complex pedigrees. We planted some selected F1 seeds in the greenhouse during the winter of 2009 to accelerate development of some specific populations.

The 2008 F2 field generation was selected for early maturity, particularly for indeterminate types of all market classes. Individual plants were bagged, stored and then threshed during the fall-winter period for re-selection on the basis of seed characteristics before planting in the field as F3s in the summer of 2009. F2 populations from crosses positive for at least one molecular marker for CBB tolerance were grown in a CBB nursery, inoculated with the pathogen and selected for tolerance. Selected plants were harvested as with regular F2s and will be screened for seed characteristics before returning to the CBB nursery as F3 plots in 2009.

For the F3 generation, selected plots were evaluated on the basis of maturity and agronomic characteristics such as canopy development and pod clearance. Selections with sufficient amounts of desirable quality and seed types will be planted as F4 microplots in 2008. Populations selected as having tolerance to CBB at the F2 in the 2007 CBB nursery were grown again in the nursery and selected based on tolerance to CBB and, opportunistically, halo blight as well. These selections will be screened again for seed characteristics and entered into F4 preliminary trials along with the regular F4s.

In the summer of 2008, 17 F4 preliminary yield trials were grown with a total of 1250 lines. One replicate of each trial was grown at Outlook and a second replicate was grown for 11 of the tests at Saskatoon as well.

Seven advanced yield trials consisting of 2-replicates of a total of about 180 breeding lines were evaluated. Six trials were grown at 4 locations (Saskatoon, Oxbow, Outlook and Rosthern) and one was grown only at Saskatoon and Outlook. One elite bean yield trial representing about 35 breeding lines was grown at Saskatoon, Oxbow, Outlook and Rosthern.

The Short Season Narrow Row Dry Bean Cooperative Trial (27 entries including checks) was established at Saskatoon, Rosthern, Oxbow, Outlook, Thornhill MB and Lethbridge AB. Additional entries were supplied for the Long Season Narrow Row trial in Manitoba. Data were used to develop recommendations for registration. The indeterminate CBB tolerant slow-darkening pinto bean line 2793CBB was proposed for registration based on yield, quality, anthracnose resistance, excellent post-harvest colour and early maturity. The slow darkening pinto bean line 2005s-1 was proposed based on excellent post-harvest seed quality and early maturity.

The 2008 field season was cooler than normal and halo blight was evident in many populations. All sites were harvested this year. The Crop Development Centre installed a linear irrigation system for development as a disease screening tool beginning in the 2008 field season which was used successfully for the CBB nursery.

2. Specialty market classes

We are continuing to develop breeding lines specifically for target markets. The first stage is development of the proper seed coat, seed size and seed shape characters combined with suitable adaptation and agronomic characteristics for Saskatchewan production.

Yellow bean breeding lines were evaluated in replicated trials in 2008 showed promise in terms of both yield potential and quality. One was entered into the 2008 Short Season Narrow Row Coop and performed quite well. The only other yellow bean line in Coop trials in western Canada was an American line that only matured in the Bow Island AB region. Flor de mayo types were included as entries in the 2008 Short Season Narrow Row Coop Trial. We continue to make headway on flor de junio types having finally broken the linkage between the seed coat colour/pattern and terrible plant architecture in 2008. We are converting carioca types to slow-darkening seed coats and incorporating CBB tolerance before further testing at the coop level.

We are continuing our work to rapidly convert bean varieties and breeding lines of all relevant market classes to common bacterial blight resistance using molecular markers as part of an NSERC CRD project. This project ended in December 2008 but it will continue as part of the regular breeding program now that it is more or less routine.

Pulse Crop Pathology

Principal Investigator: Sabine Banniza

Overall Objective

The overall objective of the pulse crop pathology program is to further knowledge of host-pathogen systems in pulse crops and to exploit this knowledge for resistance breeding and disease management.

Specific objectives

- To support efforts in continuously improving resistance to the major diseases, in developing varieties with resistance to the secondary diseases, and in screening for resistance to potentially new diseases;
- To monitor changes in pathogen populations in order to develop suitable screening protocols for disease resistance screening, and to adapt disease management strategies accordingly;
- To investigate the biology of newly emerging diseases with the objective to support breeding efforts, assess the economic importance of these diseases and lay the foundation for further research into disease management strategies, if required;
- To research the host-pathogen interactions in pulse crops to gain a better understanding on how resistance in pulse crops function and why it can break down.
- To develop disease management strategies for pathogens of economic importance in Saskatchewan.

Plan to Achieve Objectives

1. Screening for resistance in disease nurseries:

Disease nurseries were established in 2008 in the field to evaluate resistance of advanced breeding material and co-op trials to mycosphaerella blight and powdery mildew (pea). Testing for ascochyta blight and anthracnose (race Ct1) of lentil were conducted under controlled conditions in the greenhouse.

Lentil:

Three tests, LCYTA, LCYTB and LCYTC with a total of 84 entries were established under greenhouse conditions.

For anthracnose testing, entries were seeded in cell trays with 10 replicate cells per entry. Plants were grown for 3 weeks prior to inoculation with a spore suspension of *C. truncatum* isolate CT-35 (race 1) at a concentration of 5×10^4 spores mL^{-1}, incubated for 24h in a humidity chamber and then transferred to a greenhouse bench. Ratings were taken 7 days after inoculation using a 0-5 scale (AN, 0: no lesions; 1: a few superficial lesions at stem base; 2: up to 25% of stem area covered by superficial or deep lesions; 3: 25-50% of stem area covered by a mix of superficial and deep lesions; 4: 50-75% of stem area covered by deep, penetrating and coalesced lesions; some shoot die-back; 5: more than 75% of stem area covered by deep, penetrating and coalesced lesions, severe shoot die-back). All data were analyzed by the GLM procedure in SAS, using LSD to separate means.

Anthracnose development was good under controlled conditions ranging from 0.85 to 4.7 with CDC Robin as the resistant check at the low end of the scale. Severity levels were medium to high allowing for the differentiation of the resistant from susceptible checks. Several entries were as resistant to anthracnose as CDC Robin.

For ascochyta blight screening, entries were seeded at 4 seeds per 4" square pot with 4 replicate pots per entry. Plants were grown for 3 weeks prior to inoculation with a spore suspension of *A. lentis* isolate AL-61 at a concentration of 5×10^5 spores mL^{-1}, incubated for 48h in a humidity chamber and then transferred to a greenhouse bench under misting irrigation. Ratings were taken 14 days after inoculation using the Horsfall-Barratt (HB) scale. HB data were transformed into percentage data. All data were analyzed by the GLM procedure in SAS, using LSD to separate means.

Ascochyta blight severity ranged from 18% to 71%, allowing for a good differentiation between the susceptible and resistant checks. Many lines in the coop tests had resistant levels similar to the resistant check CDC Robin.

Eight pre-breeder lines were selected from above the co-op trials and a total of 737 sub-lines were tested for ascochyta blight and anthracnose resistance following the same protocols as described above.

Eight lentil lines were put forward at the PRCPSC meetings to be supported for registration in February 2009, and

In addition to the lentil co-op trial, the regional trial was screened in the field under the new irrigation system. Twenty-four entries were planted in 3 replicated plots and were inoculated on July 28, 2008 with sterilized wheat grains colonized with *Ascochyta lentis* at a concentration of approximately 10 g m^{-2}. Ascochyta blight severity was assessed on August 14, 2008 using the Horsfall-Barratt scale, and ranged from 14 to 50%.

Pea:

Mycosphaerella blight severity was assessed in replicated trials on 24 marrowfat elite lines, 48 co-op entries, 107 elite lines, 639 sub-lines of pre-breeder lines, 26 regional trial lines, and 207 entries from various international programs (e.g. USDA, Australia, Czech Republic) or in topic specific trails. Severity of mycosphaerella blight medium and was assessed using the Xue scale (0-9). The co-op entries were also assessed for powdery mildew resistance.

2. Evaluation of yield loss due to Ascochyta pisi

A small experiment was established at Saskatoon (2 locations: Investigation, SPG) to assess yield loss due to *A. pisi* in pea cultivars CDC Bronco (resistant) and Cooper (susceptible). Both cultivars were seeded in a randomized complete block design with 4 replications and 2 treatments, a fungicide application and an untreated control. Plots were inoculated with *A. pisi*-colonized sterile fababean seed in early to mid July. An additional inoculation by spraying a spore suspension of the fungus was applied on July 21. Two applications of Headline, on July 27 and on August 7, respectively, were applied to the fungicide treated plots. Severity of *A. pisi* (AP) and of *M. pinodes* (MP) was assessed on July 24, August 1 and on August 13 (Investigation) and August 18 (SPG) using the Horsfall-Barratt scale.

Disease severity ranged from 9 to 80% for AP, and from 9 to 38% for MB. Higher disease levels were observed at Investigation. There were no differences between the cultivars in their response to *A. pisi*. Fungicide applications significantly reduced AP severity by approximately 20% on average, and increased yield at Investigation. These results suggest that AP can indeed affect seed yield of pea under medium to high disease pressure.

3. Reducing production risks of chickpeas by optimizing fungicide applications (funded through ADF and SPG)

Despite the introduction of cultivars with higher levels of resistance, ascochyta blight still represents a serious threat to production and can cause a significant increase in production cost through fungicide applications and/or yield and quality loss. Whereas data on optimum ascochyta blight management including fungicide timing is available for susceptible cultivars, this data has not yet been generated for the new generation of cultivars with partial resistance. To develop disease management strategies for these cultivars, this project was initiated to evaluate different timings and frequencies of fungicide applications, and to assess the efficacy of different fungicide rotations on ascochyta blight control in chickpea.

Experiments were conducted at Saskatoon and Swift Current in 2008. Application frequency and timing was evaluated on the partially resistant chickpea cultivars CDC Vanguard, CDC Luna, and CDC Frontier. As insufficient seed was available for FLIP 98-135C, CDC Chico, a susceptible kabuli chickpea, was used instead.

At Saskatoon, the growing season of 2008 was characterized by a cool and unusually dry spring. The first major precipitation occurred in late June, followed by more rain during July, August and September. Ascochyta blight did not develop before early July, but progressed rapidly thereafter, in particular in the susceptible cultivar CDC Chico. At Swift Current, significant rain events occurred throughout the season making 2008 a wet season in the area. As a result, first disease symptoms were observed at the seedling stage already, ascochyta blight severity increased steadily throughout the growing season, thus reached higher levels than at Saskatoon.

First year evaluation of different frequencies and timings of fungicide applications revealed that Treatments 4 (seedling, vegetative and mid-flower application), and 8 (5 applications) resulted in best protection and increased yields at least in the more susceptible cultivars CDC Chico and CDC Luna. CDC Frontier and CDC Vanguard had lowest AB levels and also showed lowest responses to fungicide applications, suggesting that fewer, well targeted applications may be sufficient. First year evaluation of different fungicide rotations suggest that a rotations of Headline Duo and Proline or Bravo may provide more effective control than other rotations, evident in reduced AB severity at both locations and yield increases at Swift Current.

For more details, please refer to REDUCING PRODUCTION RISKS OF CHICKPEAS BY OPTIMIZING FUNGICIDE APPLICATIONS (ADF Project #: 20070097; MIDAS #: 000623 SPG Project #: AGR0801), Annual Report January 2009, S. Banniza, Y. Gan, B. Tar'an)

4. Research on Colletotrichum truncatum causal agent of anthracnose on lentil (Funded through NSERC)

The fungus *Colletotrichum truncatum* (Schw.) Andrus and Moore causes lentil anthracnose, which can severely damage lentil production in western Canada. Two races, Ct0 and Ct1, have been identified in the pathogen population. Differences in the infection process between the two races have not been described. The objective of this project is to investigate differences in the infection process of races Ct0 and Ct1 using the fully susceptible cultivar Eston and the race Ct1-resistant cultivar CDC Robin.

An extensive anthracnose survey in lentil crops was conducted in late July / early August of 2008, covering approximately 70% of the lentil growing region of Saskatchewan based on 2007 Crop Statistics for 2007 of the Saskatchewan Ministry of Agriculture ((http:\\www.agriculture.gov.sk.ca) (Fig. 3). Growing conditions had been very dry and cool in May and June 2008, delaying crop and disease development. A first major rain occurred in mid June in most areas followed by a second period with higher precipitation in mid July. Generally, the severity of all diseases was very low in lentil crops, and only slight infections with *C. truncatum* were detected in the crops. Lentil crops in the south-west were for the most part disease free, so more intensive surveying was not pursued further. One field in eastern Saskatchewan was identified where anthracnose severity was moderate, and a systematic sampling of infected plant material in this field was conducted. Infected plant material was collected and *C. truncatum* was isolated following standard procedures. To date, 175 isolates have been obtained from this field. Isolation of *C. truncatum* from other samples collected across the region is still ongoing. To date, 31 isolates from 14 fields have been isolated.

We now have 114 isolates from a single field in the western part of Saskatchewan (near Conquest in Crop District 6B, collection in 2007), 175 from a field in eastern Saskatchewan (near Dysart in Crop District 5A), and anticipate to obtain a minimum of 100 isolates from various crops across the lentil growing region. Screening for polymorphic primers will commence in the New Year. If growing conditions in 2009 will be more conducive to disease development, we may collect more infected lentil plants in the central and southern part of Crop District 3BN, and Crop District 3AN. These are important lentil production areas but crops were disease-free in fields visited in 2008. DNA extraction, screening for polymorphic markers and initiation of the molecular population study will commence in January 2009.

A random selection of 144 ascospore derived F_1 isolates together with the parental isolates CT-30 (race Ct0) and CT-21 (race Ct1) has been phenotyped using a standard protocol. Spore suspensions of isolates were inoculated onto 3-week old lentil cultivars Eston (susceptible to both races), CDC Robin (resistant to race Ct1), interspecific recombinant inbred line LR59 (resistant to both races), VIR 421 (partial resistance to both races). Disease severity of stems and leaves, and shoot die-back were assessed 7 days post-inoculation.

Results revealed that frequency distributions of severity ratings of isolates were continuous and skewed towards susceptibility on Eston and VIR421, though somewhat less so for VIR421. Distributions for stem lesions and shoot die-back were continuous and skewed towards resistance on LR59, while that for leave lesions was normally or near-normally distributed. All frequency distributions on CDC Robin appeared to follow a bimodal distribution on CDC Robin, most clearly based on stem lesions (Fig.4). Data also suggest that leaves are more susceptible than stems; however under field conditions stem lesions are more damaging to the crop. A few F_1 isolates had higher disease ratings than the more aggressive parent CT-30 on LR 59. This was more pronounced on leaves compared to stems.

A cDNA library has been constructed using mRNA isolated from leaflets of lentil cultivar 'Eston' infected with *C. truncatum* isolate CT-21. To get a global pattern of transcript abundance, we have created a primary plasmid library without amplification. Restriction analysis of plasmids randomly isolated from this cDNA library revealed that this library has over 95% transformation efficiency. So far, the 5'-end single pass sequencing of clones generated 656 high-quality expressed sequence tags (ESTs). These EST sequence were queried against the

NCBI non-redundant protein database and the Pathogen–Host Interactions database using BLASTX (http://www.ncbi.nlm.nih.gov/BLAST), and against the Consortium for the Functional Genomics of Microbial Eukaryotes (COGEME) EST database (http://cogeme.ex.ac.uk/) using TBLASTX. BLASTX and TBLASTX analysis of ESTs showed that 280 (42.6%) ESTs were fungal origin. In addition to fungal house-keeping genes which represented 50% of the total, genes encoding fungal nutrient transporters, secreted cell wall degrading enzymes, transcriptional factors, proteins involved in cytoskeleton/trafficking, and genes of unknown function or unique to *Colletotrichum* were identified. The remaining 376 (47.4%) ESTs were identified as of plant origin. Among these 376 plant ESTs, 25 (6.6%) showed significant similarity with pathogenesis related protein-5 (PR-5; thaumatin like protein). This suggested that the transcriptome level of PR-5 protein was elevated upon biotrophic infection, indicating that the transcripts in this cDNA library are largely associated with the biotrophic stage of *C. truncatum*. From the Eston - Ct21 cDNA library, sequencing of over 5500 clones is underway at the Plant Biotechnology Institute (NRC) sequencing facility. Dr. Bhadauria is currently constructing a second cDNA library using mRNA from the Eston - Ct30 interaction.

Through database search, we have identified a number of fungal transcript targets for further *in planta* and in culture expression studies. RNAs from *in vitro* cultures under various conditions including various nitrogen, carbon and iron resources are currently in preparation.

5. *Characterization of variability in virulence among populations of Xanthomonas axonopodis pv. phaseoli causal agent of common bacterial blight (CBB) on bean*

Common bacterial blight (CBB) is a significant contributor to yield losses in dry bean with very limited options for disease management. Incorporation of resistance is considered to be the most economical and environmentally friendly approach. Although resistance to CBB has been available to breeders for a number of years the only resistant varieties are navy beans. However, dry bean production is comprised of many locally adapted varieties of many market classes grown in diverse agricultural ecosystems. Because marker-assisted selection (MAS) can increase the efficiency of selection the overall objective of this project is to develop a comprehensive strategy for biological control of CBB through resistance gene deployment in several market classes using molecular marker-assisted selection. To ensure that resistance genes used are effective against the entire population of the bacterial pathogen, a pathogen population was conducted.

Four different inoculation methods were evaluated for the purpose of this study, including piercing of cotyledons, inoculation of detached trifoliate leaves with a razor blade and multiple needles, spraying of the whole plant with a bacterial suspension and inoculation of the pods with a dissecting needle. Among those, the razor blade method was the most reliable and easiest to produce good symptoms on bean leaves and thus was selected for population studies.
Seven bean cultivars / breeding lines were selected for testing based on different sources of resistance to the CBB pathogen: HR67, OAC Rex and Weihing with resistance derived from different accessions of *P. acutifolius*, ICB10 and XR235-1-11 with resistance derived from different accessions of *P. coccineus*, and OAC Seaforth as a semi-susceptible, and CDC Pintium as fully susceptible checks.

A total of 49 strains of *Xanthomonas axonopodis* were selected for the population study including 4 from Colorado (U.S.A.) and 4 from Mexico. The remaining strains were isolated from infected bean leaves collected in the main bean growing regions of Canada.

As it is technically not possible to test all strains at the same time the experiment was designed as a split plot where strains are the main plot treatment and differential bean cultivars are the sub-plot treatments. To account for variability among sets of isolates tested at different times, main plots were arranged in a 7 x 7 simple lattice as described by Cochran and Cox (1992) and incomplete blocks have been tested over time.

Bean cultivars / lines were grown in 5' round pots at 3 seeds per pot in a mix of perlite and sunshine mix 4 (1:3). Fertilization (nutricote- granular) and staking of plants to avoid tangled vines occurred one week after planting. Plants were inoculated after 3 weeks.

For each inoculation the respective Xap strains were grown on a yeast-triptone medium for 48 h after which time the bacterial suspension was adjusted by spectrophotometer to a density of 0.32 at 620nm which is approximately equivalent to 1×10^8 colony forming units (Tar'an et al. 1998). For inoculation, plants were misted with water and kept in a humidity chamber to maintain leaf wetness. A razor blade was dipped into the bacterial suspension and a cut of approximately 1 cm length was made into the first trifoliate leaf of each plant. Plants were incubated in the humidity chamber for 24 h and then moved to an irrigated greenhouse bench. Disease severity was assessed as area necrotic tissue around the inoculation sites 3 weeks after inoculation with the help of a grid consisting of 25 squares.

Disease reaction varied widely depending upon the CBB strains and bean variety. Overall, CDC Pintium, Weihing and OAC Seaforth were the most susceptible varieties, and HR67 and OAC Rex were the most resistant varieties. In general, CDC Pintium, Weihing and OAC Seaforth revealed bell-shaped frequency distribution curves of disease ratings. All other varieties had frequency distribution curves skewed towards the low disease severity. Albertan strains were less aggressive whereas Ontarian strains were highly aggressive. A continuum of disease severities were observed on the differentials for each strain. No distinct groups of strains representing races could be discerned based on the continuous distributions of disease reactions. The resistance gene(s) in HR67 and OAC Rex were most effective against all CBB strains. The results of this study suggest that breeding for CBB resistance does not require race-specific screening.

Outcomes

The expected outcomes of the pulse crop pathology program are the release of varieties with increased levels of resistance to diseases and the availability of effective disease management strategies for producers resulting in yields of high quality and quantity, a reduction in input costs and a reduction in risk.

Outputs

Outputs for 2006-2007 are:

- Variety development

Crop varieties supported for registration:
2009

K. Bett, A. Vandenberg, S. Banniza, Q. Liu, B. Barlow, S. Ife: Pinto bean line 2793CBB

A. Vandenberg, Banniza S, Boechler S, Tullu A, Tar'an B., Ife S., Barlow B., Warkentin T., Horner J., Mazurkewich M., Thompson, M., DeSilva D.: Small red lentil line 2321-6.

A. Vandenberg, Banniza S, Boechler S, Tullu A, Tar'an B., Ife S., Barlow B., Warkentin T., Horner J., Mazurkewich M., Thompson, M., DeSilva D.: Extra small red lentil line 1897T-30A.

A. Vandenberg, Banniza S, Boechler S, Tullu A, Tar'an B., Ife S., Barlow B., Warkentin T., Horner J., Mazurkewich M., Thompson, M., DeSilva D.: Small red lentil line 2271-5.

A. Vandenberg, Banniza S, Boechler S, Tullu A, Tar'an B., Ife S., Barlow B., Warkentin T., Horner J., Mazurkewich M., Thompson, M., DeSilva D.: Small red lentil line 2321-6.

A. Vandenberg, Banniza S, Boechler S, Tullu A, Tar'an B., Ife S., Barlow B., Warkentin T., Horner J., Mazurkewich M., Thompson, M., DeSilva D.: Large red lentil line 2275-15.

A. Vandenberg, Banniza S, Boechler S, Tullu A, Tar'an B., Ife S., Barlow B., Warkentin T., Horner J., Mazurkewich M., Thompson, M., DeSilva D.: Spanish Brown lentil line 3020-6.

A. Vandenberg, Banniza S, Boechler S, Tullu A, Tar'an B., Ife S., Barlow B., Warkentin T., Horner J., Mazurkewich M., Thompson, M., DeSilva D.: Medium green lentil line3056-12.

A. Vandenberg, Banniza S, Boechler S, Tullu A, Tar'an B., Ife S., Barlow B., Warkentin T., Horner J., Mazurkewich M., Thompson, M., DeSilva D.: Clearfield medium red lentil line IBC 187.

A. Vandenberg, Banniza S, Boechler S, Tullu A, Tar'an B., Ife S., Barlow B., Warkentin T., Horner J., Mazurkewich M., Thompson, M., DeSilva D.: Clearfield large green lentil line IBC 194.

TD Warkentin, A Vandenberg, B. Tar'an, S. Banniza, K. Bett, B. Barlow, S. Ife, J. Horner, D. DeSilva: Yellow pea line CDC1897-3.

TD Warkentin, A Vandenberg, B. Tar'an, S. Banniza, K. Bett, B. Barlow, S. Ife, J. Horner, D. DeSilva: Yellow pea line CDC1897-14.

TD Warkentin, A Vandenberg, B. Tar'an, S. Banniza, K. Bett, B. Barlow, S. Ife, J. Horner, D. DeSilva: Green pea line CDC1932-201.

Varieties released through the Saskatchewan Pulse Grower's Variety Release Program:
CDC 1410 – yellow pea
CDC IBC-112 CL – small green lentil
CDC IBC-145 CL – medium green lentil
CDC IBC-194 CL – green lentil
CDC IBC-187 CL - small red lentil
CDC 1894T-1 – extra small red lentil
CDC 17885-4e – extra small red lentil

- Author and co-author of 5 technical reports / publications

Banniza, S., Gan, Y., Tar'an, B., 2009. Reducing production risks of chickpeas by optimizing fungicide applications. Annual Report to ADF and SPG, January 2009.

Tar'an, B., Holm, R., Banniza, S., 2009. Interaction of Herbicide Applications and Reaction to Ascochyta Blight in Chickpea. Annual Report to ADF and SPG, January 2009.

Banniza, S., Wei, Y., and A. Vandenberg, 2008: Pathogenic, genetic and molecular characterization and differentiation of races in Colletotrichum truncatum from lentil. Annual Report to NSERC, December 2008.

Warkentin, T., Tar'an, B., Banniza, S., Bett, K., Tullu, A., and A. Vandenberg, 2008: Strategy for Genetic Improvement of Ascochyta Blight Resistance in Chickpea (*Cicer arietinum*). Progress Report submitted to the Saskatchewan Pulse Growers and Saskatchewan Agriculture and Food, December 2008.

Lulsdorf, M., Warkentin, T., Tar'an, B., Diederichsen, A., and S. Banniza, 2008: Perennial chickpea: Potential for improving *Ascochyta* rabiei resistance. Progress Report submitted to the Saskatchewan Pulse Growers and Saskatchewan Agriculture and Food, December 2008.

- Co-author of 12 poster or oral presentations at scientific conferences and meetings

Menat J, Armstrong-Cho CL and Banniza S 2009. Lentil Anthracnose : Does Sexual Reproduction Occur in the Field ? Pulse Days 2009. Saskatoon, January 12-13, 2009. [Abstract and poster]

Cohen-Skali A, Armstrong-Cho C, Wei YD and Banniza S 2009. The anthracnose marathon: keeping up with race development. Pulse Days 2009. Saskatoon, January 12-13, 2009. [Abstract and poster]

Tar'an B, Ife S, Barlow B, Sapsford K, Banniza S, Warkentin T, Vandenberg A, and Holm FA, 2008. Effects of Herbicide Applications on Ascochyta Blight Disease in Chickpea. Pulse Days 2009. Saskatoon, January 12-13, 2009. [Abstract and poster]

Diederichsen A, Lulsdorf M, Banniza S, Tar'an B and Warkentin T 2009. Two wild relatives of the cultivated chickpea as potential sources of resistance to ascochyta blight. Pulse Days 2009. Saskatoon, January 12-13, 2009. [Abstract and poster]

Gurusay V, Banniza S, Tar'an B and Warkentin T 2009.Breeding outside the box: Possibility of using wild pea (*Pisum fulvum*) for ascochyta bight resistance in field pea breeding. Pulse Days 2009. Saskatoon, January 12-13, 2009. [Abstract and poster]

Knihniski C, Armstrong-Cho C, Heendeniya A, Bett K and Banniza S 2009. A population study to determine if races exist among the bacteria causing common bacterial blight. Pulse Days 2009. Saskatoon, January 12-13, 2009. [Abstract and poster]

Lulsdorf M, Banniza S, Diederichsen A, Grewal R, Tar'an B and Vandenberg A 2008. Improving ascochyta blight resistance in chickpea; a talk on the wild side. Proceedings of the 7th Canadian Pulse Research Workshop, November 4-7, Winnipeg, Manitoba, Canada, pp. 17-18.[Short paper and presentation]

Tar'an B, Holm FA, Banniza S, Sapsford K, Warkentin T, Vandenberg A, Ife S and Barlow B 2008. Effects of Herbicide Applications on Ascochyta Blight Disease in Chickpea. Proceedings of the 7th Canadian Pulse Research Workshop, November 4-7, Winnipeg, Manitoba, Canada, pp. 135-136. [Short paper and poster]

Cohen-Skali A, Wei YD, Vandenberg A, Banniza S 2009. Inheritance of virulence in *Colletotrichum truncatum*. Proceedings of the 7th Canadian Pulse Research Workshop, November 4-7, Winnipeg, Manitoba, Canada, pp. 94-95. [Short paper and poster]

Dokken FL, Risula D, Pearse PG, Gan Y, McDonald C, Gossen BD, Banniza S, Ta'ran B and Goodwin M 2008. Chickpea sentinel plant project – developing an early warning system for ascochyta blight. Proceedings of the 7th Canadian Pulse Research Workshop, November 4-7, Winnipeg, Manitoba, Canada, pp. 89-90. [Short paper and poster]

Menat J, Wei YD and Banniza S 2008. Mating System of *Colletotrichum truncatum*, the Causal Agent of Lentil Anthracnose. Proceedings of the 7th Canadian Pulse Research Workshop, November 4-7, Winnipeg, Manitoba, Canada, pp. 19-20. [Short paper and poster]

Menat, J., Wei, Y.D. and S. Banniza, 2008. Studies of the mating system of *Colletotrichum truncatum* (tel.: *Glomerella truncata*). Annual Meeting of the Canadian Phytopathological Society, Charlottetown, PEI, June 15-18, 2008. [Abstract and presentation]

Published:

- 3 scientific manuscripts published and submission of 1 manuscript

Mwakutuya, E. and Banniza, S., 2009. Influence of temperature and wetness duration on the development of stemphylium blight on lentil. Submitted to Plant Pathology, March 2009.

Vail, S., and Banniza, S., 2009. Molecular variability and mating type frequency of *Ascochyta rabiei* on chickpea in Canada. Australasian Plant Pathology, In press.

Fiala JV, Tullu A, Banniza S, Séguin-Swartz G and Vandenberg A 2009. Interspecific transfer of resistance to anthracnose in lentil (*Lens culinaris* Medik.). Crop Science, Manuscript ID CROP-2008-05-0260-ORA.R2, accepted on Dec 5, 2008.

Chandirasekaran, R., Warkentin, T., Gan, Y., Shirtliffe, S.J, Gossen, B.D., Tar'an, B. and S. Banniza 2009. Improved sources of resistance to ascochyta blight in chickpea. Canadian Journal of Plant Sciences 89:107-118.

- Supervision of 3 graduate students and 1 undergraduate student

One MSc student is scheduled to defend his thesis in April 2009. Two PhD students commenced their programs in January 2007. One undergraduate students conducted research projects under my supervision from September 2008 until March 2009.

Research Funding

Pulse Crop Advancement Agreement, Saskatchewan Pulse Growers, 2005 – 2010, $ 536,000 for pathology work in the pulse crop breeding programs.

Principal Investigator:

Banniza, S., Vandenberg, A. Developing screening techniques for stemphylium blight in lentil. Saskatchewan Ministry of Agriculture, ADF, 20009, $14,720.00.

Banniza, S., Tar'an, B., Gan, Y. Reducing production risks of chickpea by optimizing fungicide applications. Saskatchewan Agricultural Development Fund and Saskatchewan Pulse Grower's Association, 2008-2011. $300,000.

Banniza, S., Vandenberg, A., and Y. Wei. Pathogenic, genetic and molecular characterization and differentiation of races in *Colletotrichum truncatum*. NSERC-Collaborative Research Development Grant. Funded through NSERC and the Saskatchewan Pulse Growers, 2007-2012. $ 501,596.

Banniza, S.: From biotrophy to necrotrophy: Interaction of the hemibiotrophic fungus *Colletotrichum truncatum* with its host plants. NSERC discovery grant, 2004-2009, $112,500

Co-investigator:

Tar'an, B., Holm, R., and S. Banniza. Interaction of herbicide application and reaction to ascochyta blight in chickpea. Saskatchewan Agricultural Development Fund and Saskatchewan Pulse Grower's Association 2008-2010, $ 113,735.

Warkentin, T., Gurumasy, V., Tar'an, B. and S. Banniza. Pyramiding novel genes for resistance to ascochyta blight from *Pisum fulvum* into field pea through molecular breeding. Saskatchewan Pulse Grower's Association , 2008-2013, $335,091.

Warkentin, T., Lulsdorf, M., Tar'an, B., Banniza, S. and A. Diederichsen, 2004: Ascochyta resistance in chickpea – search for superior sources of resistance in the perennial *Cicer* species. Saskatchewan Agricultural Development Fund and Saskatchewan Pulse Grower's Association, 2004 – 2008, $600,000.

Strategies for Future Funding

Potential future funding for pulse crop pathology projects include:

- Saskatchewan Pulse Growers project funding
- Agriculture Development Fund project funding
- NSERC CRD program
- Alberta Agricultural Research Institute
- BARD (The United States – Israel Binational Agricultural Research and Development Fund) Canada-Israel Program
- CIDA

Resources required

1. Small-scale fermentation equipment to produce CBB inoculum in house.
2. Cereal grinder to grind wheat grains after inoculation, incubation and drying to prevent them from being eaten by birds

Lentil Breeding and Genetics

Principal Investigator: Albert Vandenberg

Overall Objective

- Development of high yielding lentil cultivars with resistance to foliar diseases, acceptable quality profiles for export and domestic food markets, and improved agronomic traits.

Sub-objectives
- Green lentil breeding
- Red lentil breeding
- Specialty lentil breeding

Results 2008-2009

New variety releases

In collaboration with Saskatchewan Pulse Growers, breeder seed of IBC-188 French green lentil was sent to Select seed growers in the spring of 2008, along with repeat orders of some previously released varieties.

Specialty lentil breeding

Appropriate crosses were designed in each crossing cycle with the objective of improving the quality, yield and disease resistance combinations for the following specialty market classes: French green, Spanish brown (Pardina), zero tannin red, green cotyledon, extra small red, extra large red and extra large green. Selections were made on the basis of yield potential, marketing characters and disease resistance in each of these market classes, resulting in selection of breeding lines for the advanced, elite and registration trial evaluation stream in 2009. Breeding lines selected from advanced generations were incorporated into the regular breeding nurseries, and the number of genotypes in total for this segment of the breeding program represented less than 5%. We also initiated backcrosses for rapid introgression of imidazolinone tolerance and anthracnose resistance based on 2008 field selection. Pre-breeder seed strategies were developed and implemented with commercial partners for fast-track multiplication in New Zealand in winter of 2008-9 for promising lines in the Pardina, green cotyledon and large red market classes.

Expected Outcomes of the Lentil Breeding Program

Pulse crops are currently grown on approximately 12% of the annual planted area of Saskatchewan. The potential exists for a doubling of the sustainable pulse crop area of production in the province. Expanded area of production is contingent on many factors, one of which is improved pulse crop cultivars. We expect that the area devoted to lentil production will increase by 33% from 2008 to 2009 and that this increase will be commercially sustainable in the future based on (1) Saskatchewan's increasing market share based on diversification and genetic gain and (2) an expanding world market for lentils.

Expected outcomes of the CDC lentil program include increased economic returns to producers and the pulse crop marketing industry due to the following factors.

- higher yield for all market classes
- lower input costs due to improved disease resistance and better weed control
- improved lodging resistance
- improved visual characteristics such as seed plumpness
- improved seed coat colour retention for green lentil
- larger diameter seeds for the large green and large red lentil market class
- access to new markets with improved cultivars and new market classes
- increased global market share for exports of whole and decorticated red lentil (5 dehulling plants will be operating 1-3 dehulling lines in 2009)
- increased demand for decorticated green lentil, particularly in South Asia
- maintenance and increase of lentil value by market segmentation based on consumer-driven preferences and quality traits

Activities to Achieve Objectives

Three crossing cycles were completed for both the regular and accelerated lentil breeding programs. We maintained a focus on accelerating the backcross system for rapid introgression of anthracnose race Ct0 resistance in all lentil market classes, and for imidazilinone tolerance in some market classes. We continue to make use of the tray system for intensive backcrossing. We have developed a set of donor lines in most market classes and are now including Spanish brown and large red classes. Each line is derived from back-crossing with a breeding line exhibiting resistance to anthracnose race Ct0.

Most of the F_2 lentil field nursery was successfully grown and harvested at the SPG farm in 2008. About 50% (increasing each year) of the F2 nursery, the portion with Ct0 anthracnose resistance, was grown directly in the North Seed Farm disease nursery for the first time, with good results. Seeds from up to 10,000 F_2 plants will be available for the 2009 field season after selection of individual plants for seed quality related to shape, size, cotyledon colour and seed-borne diseases. Some F_2 populations were deliberately bulk and harvested well after maturity to allow mass selection against shattering characteristics and positive selection for seed diameter and seed coat colour retention. These populations will be evaluated in future as individual F3 plants.

At the North Seed Farm lentil disease nursery in 2008, the environment was conducive for development of anthracnose. Selections from 2008 were made on the basis of seed quality characters. We now notice that specific crosses show visibly improved resistance to anthracnose in this nursery. This is the result of widening the genetic base of the lentil breeding program and of using recurrent selection to rapidly increase genetic gain for this breeding objective. F_4 preliminary nurseries (approximately 1400 breeding lines in total) were successfully grown at the SPG farm (one replicate) with the second replicate grown at Pasqua, Rosthern, Kyle or Brooks. Most sites produced yield results within an acceptable level of variability in 2008. All locations around Saskatoon were high yielding as a result of cool, wet weather in July. This provided excellent opportunities for screening for ascochyta resistance and seed coat colour retention for green lentils. As in 2007, most sites had average to above average yield. We were able to make effective selections on the basis of yield and quality. The Sutherland site was particularly effective for screening for seed borne ascochyta. We were not able, however, able to select germplasm on the basis of reaction to stemphylium blight, an emerging threat to lentil production. The 2008 F_5 advanced nursery consisted of 13 trials with a total of about 400 lines grown in 2 replicates at 5 locations. Except for Pasqua (high variability cause by poor stands due to early drought conditions), excellent and reliable data were obtained from all locations.

The 2008 F_6 elite nursery consisted of approximately 60 lines in 2 trials (2 replications) grown at 6-7 locations. Selection conditions were similar to the advanced nursery. By late October selections were made for entry into the 2009 Lentil Registration Recommendation Trials (LRRT). Single plants from space-seeded nurseries were harvested for all available lines and were subsequently screened for quality on a single plant basis.

In 2008, the LRRT A (36 entries) and LRRT B (24entries) trials were sown at 9 locations. A disease nursery (ascochyta and anthracnose) was also established Acceptable data were available from all locations except for the trials at Pasqua (early drought) and in Alberta, where extreme heat damaged trials. Trial C consisting of 18 entries was designed for evaluation of imidazolinone tolerant backcross lines and their respective recurrent parents was grown at 6 locations. Data from the complete set of trials were analysed and formed the basis for requests at the 2008 Prairie Recommending Committee for Pulses and Special Crops sub-committee meeting.

Support for registration was proposed and supported for high-yielding conventional red lentil lines in the extra small red (1897T-30, small red (2321-6, 2271-5) and large red (2275-15) classes. The three extra small red lines are specifically targeted for markets in India and the Middle East. Two imidazolinone tolerant lentil lines in the large green (IBC-194) and small red (IBC-187) market classes and a specialty green cotyledon type (3056-12) were supported for registration.

Fast track pre-breeder seed strategies were continued for breeding lines in the large red, green cotyledon, and Spanish brown market classes in collaboration with private industry partners and the Saskatchewan Pulse Growers. Appropriate winter increases were sent to New Zealand for multiplication in the fall of 2008.

Pre-breeder seed of promising lentil breeding lines was produced for most market classes in anticipation of potential release in 2010.

As in previous years, observational nurseries from ICARDA and other collaborators in Australia and the USA were grown to evaluate potential new germplasm sources for quality and agronomic traits of value to the Canadian lentil industry. Regional lentil trials consisting of 24 entries were sown at 16 locations across western Canada in 2008 (12 in Saskatchewan, 4 in Manitoba). Seed of a subset of these varieties was also supplied to the Alberta regional trial system. Data from successfully grown trials were analysed and included in the database published in the Saskatchewan seed guide for 2009.

Outputs

Outputs for 2008-2009 included the following.

- More than 50 breeding lines were entered in three lentil registration trials in February 2009.
- One small red lentil line (1897T-30a was recommended for registration in February 2009.
- Two small red lentil lines (2271-5 and 2321-6) were recommended for registration in February 2009.
- One large red lentil line (2275-15) was recommended for registration in February 2009.
- One large green lentil line (IBC-194) with imidazolinone tolerance was recommended for registration in February 2009.
- One small red lentil (IBC-187) with imidazolinone tolerance was recommended for registration in February 2009.
- One medium green specialty lentil with green cotyledons (3056-12) was recommended for registration in February 2009.
- Breeder seed of IBC-188 French green lentil with imidazolinone tolerance was released to Select seed growers in spring of 2008
- Numerous contributed and invited conference presentations and posters on lentil, faba bean were authored or co-authored, primarily at the 6th Canadian Pulse Research Workshop held in Winnipeg in November 2008, and Pulse Days 2009 (Saskatoon). See www.pulse.usask.ca and www.saskpulse.com for details.
- Extension related presentations

Invited presentations at Select Seed Growers Meeting presentation at Pulse Days 2009 at Saskatoon, SK on January 8, 2008, on the topic "New Lentil Varieties".

Invited presentations at Select Seed Growers meeting in July 2008.

Field day presentations at Swift Current and Scott, summer 2008.

Invited presentations to SPG board in June, 2008.

Invited keynote presentations "Past, Present and Future of Pulses" at Pulse Days 2009.

Invited presentation on lentil production at Rosetown, Saskatchewan, March 5, 2009.

Contributed articles and consultation on articles on new varieties and future of the pulse industry in Pulse Point magazine (2008 and 2009).

- International Activities

Participated in Saskatchewan Pulse green lentil project visit to Tamil Nadu Agriculture University in February 2009.

Invited presentation on "GxE Interactions and Effects on Quality" at the International Conference on Grain Legumes, Kanpur, India, February 14-16, 2009

Invited presentation on "View of Indian Pulses from a Canadian Perspective" at Tamil Nadu Agricultural University, February 2009.

- Scientific Manuscripts Published in 2007-2008 (lentil and pulses area)

Grewal R, M Lulsdorf, J Croser, S Ochatt, A Vandenberg and TD Warkentin. 2009. Doubled Haploid Production in Chickpea (*Cicer arietinum* L) – Role of Stress Treatments. *Accepted March 2009*, Plant Cell Reports.

Fiala, JV, A Tullu, S Banniza, G Séguin-Swartz and A Vandenberg. 2009. InterspeciesTransfer of Resistance to Anthracnose in Lentil (*Lens culinaris* Medic.). *In press*, Crop Science.

Little JP, PD Chilibeck, D Ciona, A Vandenberg and GA Zello. 2009. The effects of low and high glycemic index foods on high-intensity intermittent exercise. *In press*, International Journal of Sports Physiology and Performance.

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Lentil and Chickpea. Cereal Chemistry 85: 471-479.

Chung, H., Liu, Q., Hoover, R., Warkentin, T.D., and Vandenberg, A. 2008. "In vitro starch digestibility, expected glycemic index, and thermal and pasting properties of flours from pea, lentil and chickpea cultivars. Food Chemistry 111: 316-321.

- Student supervision (lentil and dry bean area)

M.Sc. student (Jesse Bruce) completed an M.Sc. degree in fall 2008 on the topic of red lentil milling efficiency.

Ph.D. student (Sally Vail) in progress on genetics of anthracnose resistance in lentil.

Ph.D. student (Grant Woronuk, co-supervised) completed thesis on frost tolerance in *Phaseolus*.

M.Sc. student (Warren Ward) in progress on the topic of selection for lodging tolerance in lentil.

Undergraduate thesis student (Bailey Wilmot) on the topic of carotenoid pigments in lentil seeds.

Faba Bean Breeding

Principal Investigator: Albert Vandenberg

Objective of Program

Genetic improvement of yield, adaptation, early maturity, lodging tolerance and culinary, physical and nutritional quality traits of non-traditional small-seeded seed white flowered faba beans and large-seeded food type faba beans for global markets. Investigation of nitrogen fixation capability in farm rotations.

Plan to Achieve Objectives

Approximately 150 new crosses were made in 2008. These will be evaluated in registration trials, elite yield trials, advanced yield trials, preliminary yield trials, F3 microplots, F2 nurseries and F1 nurseries (in reverse order).

Pre-breeder seed of 3 breeding lines is being produced in Mexico.

Expected Outcomes

Genetic improvement of faba bean and uptake by Saskatchewan farmers and processors for food, feed, and use in rotations for improving nitrogren levels in the soil.

Expected Outputs

We hope to release the three breeding lines as cultivars in 2009-10 through a commercial partner to be chosen in conjunction with the Sask Pulse Growers Association.

APPENDIX I

Personnel Contributing to CDC Plant Breeding and Research Programs

CROP GENETIC IMPROVEMENT THEME – PULSE BREEDING, 2008-2009			
CATEGORY	STAFF	PERSON	SALARY RANGE
		MONTHS	(12 months)
Associate Professor	Warkentin, T.D.	12.00	
Technician	Horner, J.	12.00	
TOTAL PAID PERSON MONTHS		24.00	
CONSULTANTS & SUPPORT STAFF PAID FROM OTHER FUNDING			
Communications Officer	Gingera, G.	**TECHNICAL STAFF**	
Grad Student (M.Sc.)	Delgerjav. O.	Alizadeh, M.	Luster, L.
Grad Student (M.Sc.)	Frimpong, A.	Ascon, E.	Mazurkewich, S.
Grad Student (Ph.D.)	Rehman, A.	Atuku, H.	Miller, J.
Grad Student (Ph.D.)	Vail, S.	Badana, M.S.	Parada, M.
Grad Student (Ph.D.)	Ubayasena. L.	Bandara, C.	Pelemis, L.
Manager, Breeder Seed Operation	Benallack, D.	Breitkreutz, C.	Prado, T.
Postdoctoral Fellow	Rehman, A.	Bulka, P.	Siemens, J.
Professor	Vandenberg, A.	Carigan, M.	Tang, L.
Professor, Assistant	Bett, K.E.	Chelak, S.	Thompson, M.
Professor, Assistant	Tar'an, B.	Chunluunbaatar, D.	Vera, C.
Professional Research Assoc	Grewal, R.	Dament, T.	Wanniachichi, S.
Professional Research Assoc	Gurusamy, V.	Delcid, M.	Weerasinghe, A.
Professional Research Assoc.	Marles, S.	Ells, C.	**SUMMER STUDENTS**
Professional Research Assoc.	Thavarajah, D.	Gonzalez, A.	Ament, T.
Professional Research Assoc.	Tullu, A.	Hashemi, P.	Heendeniya, A.
Professional Research Assoc.	Vijayan, P.	Hernandez, D.	Karchewksi, T.
Research Assistant	Barlow, B.	Hernandez, L.	Wilmot, B.
Research Assistant	De Silva, D.	Hoggard-Lulay, B.	
Research Assistant	Sapsford, K.	Ife, S.	
Research Officer	Lulsdorf, M.	Kostovska, M.	
Secretary	Ouellet, C.		
Superintendent, Field Operations	Blomquist, K.		

CROP GENETIC IMPROVEMENT THEME - PULSE PATHOLOGY, 2008-2009			
CATEGORY	STAFF	PERSON	SALARY RANGE
		MONTHS	(12 months)
Associate Professor	Banniza, S.	12.00	
Technician	Boechler, S.	12.00	
TOTAL PAID PERSON MONTHS		24.00	
CONSULTANTS & SUPPORT STAFF PAID FROM OTHER FUNDING			
Communications Officer	Gingera, G.		**TECHNICAL STAFF**
Grad Student (Ph.D.)	Cohen-Skali, A.		Knihniski, C.
Grad Student (Ph.D.)	Menat, J.		Hashemi, P.
Grad Student (Ph.D.)	Wang, J.		
Professor, Assistant	Bett, K.E.		**SUMMER STUDENTS**
Research Assistant	Cho, C.		Cochard, M.
Research Assistant	Sapsford, K.		Le. T.
Secretary	Ouellet, C.		Meduric, T.
Superintendent, Field Operations	Blomquist, K.		Shahid, F.

CROP GENETIC IMPROVEMENT THEME - FLAX PROGRAM 2008-2009			
CATEGORY	STAFF	PERSON MONTHS	SALARY RANGE (12 months)
Professor	Rowland, G.G.	12.00	
Technician	Farkas, G.	6.00	
Technician	Jackle, K.	6.00	
TOTAL PAID PERSON MONTHS		24.00	
CONSULTANTS & SUPPORT STAFF PAID FROM OTHER FUNDING			
Communications Officer	Gingera, G.		**TECHNICAL STAFF**
Grad Student (M.Sc.)	Chatfield, P.		Boon, B.
Grad Student (M.Sc.)	Coetzee, N.		Bulka, P.
Grad Student (Ph.D.)	Mitra, S.		Ells, C.
Manager, Breeder Seed Operation	Benallack, D.		Froese, S.
Secretary	Ouellet, C.		Luster, L.
Superintendent, Field Operations	Blomquist, K.		Siemens, E.
			SUMMER STUDENTS
			Pearson, E.
			Zourmpaki, E.

CROP GENETIC IMPROVEMENT THEME – SPRING WHEAT 2008-2009			
CATEGORY	STAFF	PERSON	SALARY RANGE
		MONTHS	(12 months)
Professor	Hucl, P.J.	12.00	
Technician	Trowell, G.	12.00	
TOTAL PAID PERSON MONTHS		24.00	
CONSULTANTS PAID FROM OTHER FUNDING			
Communications Officer	Gingera, G.	**TECHNICAL STAFF**	
Manager, Breeder Seed Operation	Benallack, D.		Braitenbach, H.
Research Officer	Knievel, D.		Bulka, P.
Research Officer	Dyck, J.		Cardenas, M.
Secretary	Ouellet, C.		Dyck, M.
Superintendent, Field Operations	Blomquist, K.		Ells, C.
			Gonzalez, F.
			Grieman, M.
			Ishmaeel, M.
			Jackle, K.
			Luster, L.
			McJannet, T.
			Siemens, E.
			Navarro, L.
			Numa
			Pizarro, L.
			Saldana, R.
			Zou, S.
		SUMMER STUDENTS	
			Dyck, M
			McJannet, T.
			Schneider, C.
			Van Everdink, K.

CROP GENETIC IMPROVEMENT THEME – DURUM/HIGH YIELDING WHEAT 2008-2009			
CATEGORY	STAFF	PERSON	SALARY RANGE
		MONTHS	(12 months)
Associate Professor	Pozniak, C.J.	12.00	
Technician	Hirji, N.	6.00	
Technician	Lawrie, R.	6.00	
TOTAL PAID PERSON MONTHS		24.00	
CONSULTANTS PAID FROM OTHER FUNDING			
Communications Officer	Gingera, G.	**TECHNICAL STAFF**	
Grad Student (M.Sc.)	Ramachandran, A.		Babonich, R.
Grad Student (M.Sc.)	Reimer, S.		Bulka, P.
Manager, Breeder Seed Operation	Benallack, D.		Dias, F.
Professor	Chibbar, R.N.		Doepker, M.
Professional Research Associate	Singh, A.		Ells, C.
Postdoctoral Fellow	Ruan, Y.		Lawrie, R.
Research Assistant	Bandla, N.R.		Lockhart, K.
Research Assistant	Munoz Florez, C.		Luster, L.
Secretary	Ouellet, C.		Morrison, J.
Superintendent, Field Operations	Blomquist, K.		Niebrugge, R.
			Peters, J.
			Tang, V.
			Tomita, A.
			Wiebe, K.
		SUMMER STUDENTS	
			Bell, J.
			Pryce, S.
			Williams, D.

CROP GENETIC IMPROVEMENT THEME - BARLEY/OAT PROGRAM 2008-2009			
CATEGORY	STAFF	PERSON	SALARY RANGE
		MONTHS	(12 months)
Professor	Rossnagel, B.G	12.00	
Research Assistant	Duncan, S.	12.00	
TOTAL PAID PERSON MONTHS		24.00	
CONSULTANTS & SUPPORT STAFF PAID FROM OTHER FUNDING			
Communications Officer	Gingera, G.	**TECHNICAL STAFF**	
Grad Student (M.Sc.)	Camm, G.		Bateman, M.
Grad Student (Ph.D.)	Ngantcha, A.		Bulka, P.
Grad Student (Ph.D.)	Zatorski, T.		Carcamo-Angulo, E.
Manager, Breeder Seed Operation	Benallack, D.		Colak, N.
Professor	Scoles, G.J.		Ells, C.
Professor, Associate	Shirtliffe, S.J.		Frey, D.
Professional Research Associate	Grewal, T.		Hay, D.
Research Assistant	Camm, G.		Lessa, S.
Research Assistant	Voth, D.		Luster, L.
Research Assistant	Zatorski, T.		Mac, M.
Research Officer	Eckstein, P.		Pecar, M.
Secretary	Ouellet, C.		Paul, H.
Superintendent, Field Operations	Blomquist, K.		Popiel, J.
			Siemens, E.
			Semenoff, K.
			Zhang, S.
		SUMMER STUDENTS	
			Ackerlund, R.
			Anders, A.
			Badduke, K.
			Copeland, L.
			Ibrahimoglu, I.
			Walsh, K.

CROP GENETIC IMPROVEMENT THEME – CEREAL PATHOLOGY, 2008-2009			
CATEGORY	STAFF	PERSON	SALARY RANGE
		MONTHS	(12 months)
Assistant Professor	McCartney, C.A.	12.00	
Technician	Regier, R.	6.00	
Technician	Dament, T.	6.00	
TOTAL PAID PERSON MONTHS		24.00	
CONSULTANTS & SUPPORT STAFF PAID FROM OTHER FUNDING			
Communications Officer	Gingera, G.		**TECHNICAL STAFF**
Grad Student (M.Sc.)	Matlock, E.		Fisher, S.
Secretary	Ouellet, C.		Siemens, E.
Superintendent, Field Operations	Blomquist, K.		Stonehouse, R.
			Woytowich, J.
			SUMMER STUDENTS
			Dick, L.
			Taylor, J.
			Watson, J.

CDC OPERATIONAL SUPPORT 2008-2009

CATEGORY	STAFF	PERSON MONTHS	SALARY RANGE (12 months)
Director, Managing	Murrell, D.C.	12.00	
Administrative Officer	Freeman, M.	6.00	
Farm Assistant	Epp, E.	12.00	
Research Officer	Arganosa, G.	12.00	
Research Officer	Perron, C.	12.00	
Secretary	Lee, M.	12.00	
Secretary	Stevens, S.	12.00	
Technician	Black, B.	12.00	
Technician	Cardenas, M.	4.00	
Technician	Clauson, D.	12.00	
Technician	Frey, D.	3.00	
Technician	Hassard, D.	12.00	
Technician	Lynn, P.	12.00	
Technician	Parada, M.	3.00	
Technician	Tang, V.	3.00	
Technician	Weerasinghe, A.	4.00	
Summer Student	Stene, T.	4.00	
TOTAL PAID PERSON MONTHS		147.00	

CONSULTANTS & SUPPORT STAFF PAID FROM OTHER FUNDING

Communications Officer	Gingera, G.		
Manager, Breeder Seed Operation	Benallack, D.		
Manager, Greenhouse	Bantle, J.		
Secretary	Ouellet, C.		
Superintendent, Field Operations	Blomquist, K.		
Technician, Breeder Seed Operation	Ells, C.		
Technician, Farm Operations	Bulka, P.		
Technician, Field Operations	Luster, L.		
Technician, Greenhouse	Siemens, E.		